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Motivation and Learning of Non-Traditional Computing Education Students in a Web-based Combined Laboratory

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Motivation and Learning of Non-Traditional Computing Education Students in a Web-Based Combined Laboratory

By

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We hereby certify that this dissertation, submitted by Michael Green, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

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Hands-on experiential learning activities are an important component of computing education disciplines. Laboratory environments provide learner access to real world equipment for completing experiments. Local campus facilities are commonly used to host laboratory classes. While campus facilities afford hands-on experience with real equipment high maintenance costs, restricted access, and limited flexibility diminish laboratory effectiveness. Web-based simulation and remote laboratory formats have emerged as low cost options, which allow open access and learner control. Simulation lacks fidelity and remote laboratories are considered too complex for novice learners.

A web-based combined laboratory format incorporates the benefits of each format while mitigating the shortcomings. Relatively few studies have examined the cognitive benefits of web-based laboratory formats in meeting computing education students' goals. A web-based combined laboratory model that incorporates motivation strategies was developed to address non-traditional computing education students' preferences for control of pace and access to learning. Internal validation of the laboratory model was conducted using pilot studies and Delphi expert review techniques. A panel of instructors from diverse computing education backgrounds reviewed the laboratory model. Panel recommendations guided enhancement of the model design.

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Chapter One

Introduction

Context

Laboratory exercises are an important component of computing education curricula. Student discovery, increased understanding of course concepts, and practical experience are attributed to laboratory experiences (Abdulwahed & Nagy, 2011; Chao, 2010). Practice with real-world computing equipment prepares students for work in a corporate setting.

Several laboratory configurations have been implemented in computing education courses. The most familiar format, *Hands-on laboratories* are maintained in local campus facilities. Students carry out experiments while in the presence of real experimental equipment (Ma & Nickerson, 2006). Hands-on laboratories are expensive to maintain and have accessibility and flexibility restrictions (Chao, 2010; Choi, Lim, & Oh, 2010; Wolf, 2010).

Accessible through the World Wide Web, *Virtual laboratories* were developed to address the limitations of hands-on laboratories. The term virtual laboratory has been used to describe more than one web-based laboratory format. Burd, Conway, and Seazzu (2009) noted a virtual laboratory provides access to expensive computing resources much like a hands-on laboratory except students need not be physically present. Wolf (2010) depicted a virtual laboratory as manipulating real experimental equipment remotely. In recent studies Abdulwahed and Nagy (2011), Chen (2010), and Konak, Clark, and Nasereddin (2014) defined virtual laboratories as simulations of real equipment that emulate physical laboratory experiments. The virtual laboratory label does not clearly distinguish between various laboratory formats. The terms *Web-based simulation laboratory, web-based remote laboratory, and web-based combined laboratory* will be used to differentiate the virtual laboratory formats.

Web-based simulation laboratories are accessed through the Internet and use software to replicate laboratory experiments. Simulation software is inexpensive, models real laboratory equipment, and facilitates multiple observations of the experimental process (Rutten, Van Joolingen, & Van der Veen, 2012). Reduced fidelity is a constraint of simulation software (Abdulwahed & Nagy, 2011; Cano, 2010; Wolf, 2010).

Web-based remote laboratories allow learners to experiment in an authentic computing environment using real computer hardware and software with significantly lower operating expenses than hands-on laboratories (Corter, Esche, Chassapis, Ma, & Nickerson, 2011; Uludag Guler, Karakus, & Turner, 2012). Students manipulate experimental equipment remotely and laboratories can be shared among multiple learners without temporal or physical restrictions (Wolf, 2010). Remote laboratories have been criticized for a lack of physical presence and functionality that is too complex for novice learners (Uludag et al., 2012; Xu, Huang, & Tsai, 2012).

Web-based combined laboratories integrate multiple laboratory formats and learning resources. An advantage of combined laboratories is flexible access to a range of materials that allow students to review and rehearse experimental concepts prior to completing a laboratory assignment. In a combined laboratory format web-based simulation was shown to help inexperienced novice learners prepare for more complex hands-on laboratories (Abdulwahed & Nagy, 2011; Cano, 2010; Lahoud & Krichen, 2010).

Problem Statement and Goal

In a review of laboratory studies in technology disciplines, Ma and Nickerson (2006) noted the relative scarcity of laboratory research in computing education disciplines. Many studies examined technology infrastructure rather than academic achievement in computing education laboratories (Corter et al., 2011; Konak et al., 2014). Additionally, Corter et al. (2011) recommended studies to address the cognitive benefits of web-based laboratories in meeting learner goals rather than arguing the relative merits of different delivery technologies. In a study of how student demographic characteristics influence laboratory preferences Lahoud and Krichen (2010) suggested further research into the benefits of web-based laboratories with different student populations. Comprising 42% of the total U.S. enrollment in 2010, non-traditional students are an important sector of the undergraduate population with unique learning challenges (NCES, 2011). Kim and Frick (2011) noted that adult motivation in self directed web-based learning environments is complex and emphasized the need for research in other web-based settings. The problem identified for investigation is the need for further research to understand how non-traditional computing education students experience motivation and learning in a web-based laboratory (Kim & Frick, 2011; Konak et al., 2014; Lahoud & Krichen, 2010).

Non-traditional students are over 25 with job, family and community commitments that compete with academics for their time, money, and energy (Rowen-Kenyon, Swan, Deutsch & Gansneder, 2010). The academic needs of non-traditional students are unique.

Computer based formative learning materials that promote learner control and progress evaluations are preferred by non-traditional students (Newman & Clure, 2012). Web-based course materials allow influence over the time, location, and duration of learning to accommodate student schedules and support motivation (Joliffe, Ritter & Stevens, 2012).

Motivation is associated with goal setting, achievement, and learning (Driscoll, 2005; Kim & Frick, 2011). The Keller (2010) model of motivation consists of four categories necessary for motivating learners; Attention, Relevance, Confidence and Satisfaction (ARCS). The ARCS model provides a framework to design and implement course materials that motivate learners. A web-based combined laboratory model based on the ARCS motivation framework was developed to meet the distinctive needs of non-traditional computing education students and stimulate increased motivation and learning (Green, 2012).

Using the ARCS model framework the web-based combined laboratory model incorporates computer based learning, simulation, and remote hands on activities (Green, 2012). Motivation and learning require *attention* be captured and maintained through a variety of materials that make the learning experience stimulating and interesting (Keller, 2010). The combined laboratory employs computer based learning, multimedia, and hands-on exercises to provide instructional variety to maintain attention. *Relevance* is gained by meeting individual needs in ways that are useful in the lives of the students. The topics presented in the study laboratory are closely aligned with objectives students must achieve to succeed. Learners gain *confidence* through completion of activities in which they control their own success. Confidence results from the presentation of laboratory materials in manageable units that allow students' control over the time and pace of learning. Ultimately, *satisfaction* comes from learning a challenging computing skill through completion of a laboratory assignment.

The benefits of the ARCS model for non-traditional learners have been documented. Bohlin, Milheim, and Viechnicki (1993) created a prescriptive tool based on the ARCS model for designing motivational adult instruction. Their model addressed the challenges faced by educators and instructional designers in teaching adults. The authors developed practical strategies to increase learner motivation in computer courseware. ChanLin (2009) concluded the ARCS model was a valuable guide for planning and implementing a web-based course. Motivational behavior was observed in students as a result of self-pacing of assignments, frequent feedback from the instructor, and successful achievement of difficult tasks. Cook, Beckman, Thomas, and Thompson (2009) used the ARCS model to study motivation in web-based course designs adapted to learners' previous experiences. Although not all students were motivated by the adaptive design, the researchers noted higher knowledge scores with participants who also perceived a course as interesting and relevant. Motivation is closely linked to the important academic goals of learning, self-efficacy, and self-direction (Driscoll, 2005; Kim & Frick, 2011).

The goal of this study was the design, internal validation, and enhancement of a web-based combined laboratory model that incorporates ARCS motivation strategies to support non-traditional computing education student motivation and learning. Branch and Kopcha (2014) described an instructional design model (IDM) as a tool "to visualize, direct, and manage processes for creating high-quality teaching and learning materials" (p. 77). An IDM should establish a learning environment that addresses the unique qualities of different learner populations, learning environments, delivery systems, and specific design philosophies (Richey, 2005). The web-based combined laboratory model was designed to promote non-traditional computing education student motivation and learning using the ARCS model of motivation as a theoretical underpinning.

Richey (2005) noted that internal and external validation should be a natural part of the IDM development process and formative evaluation that takes place during the design process. Many models are directed toward instructor integration of technology into their classes (Richey & Klein, 2014). This study focused on the internal validation of the web-based combined laboratory model components and its use.

The validation process can be described as an examination of the extent to which an IDM is adaptable, practical, and usable (Richey, 2005; Richey & Klein, 2007). *Adaptability* is associated with the usefulness of a model in a range of design projects and the capacity to accommodate a variety of content, delivery systems, and instructional strategies. An IDM is considered *practical* when it is cost effective and can function well with different academic cultures, resources, course environments, and diverse learner populations. A *usable* IDM can be implemented by expert and novice designers under most conditions.

The study used design and development research methods to validate internally the web-based combined laboratory IDM (Richey & Klein, 2007). Expert review is among the most common approaches to internal validation (Richey, 2005). A Delphi panel of experienced university instructors internally validated the ARCS supported model design and the extent to which it is adaptable, practical, and usable for computing students in the context of a local campus classroom learning environment.

Research Questions (RQs)

The following questions guided this investigation.

RQ1. How are web-based laboratories currently utilized in undergraduate computing education courses?

RQ2. How must an ARCS - supported web-based combined laboratory model be revised to promote the motivation and learning of non-traditional computing education students?

RQ3. What are the reactions of experienced computing education instructors to the ARCS – supported web-based combined laboratory in terms of adaptability, practicality, and usability?

RQ4. What modifications are needed to improve the ARCS - supported web-based combined laboratory model in terms of perceived adaptability, practicality, and usability?

The first research question was answered with a thorough literature review into existing laboratory environments in computing education. The second research question was answered through a generic instructional design and development process that included recommendations gathered through pilot studies and expert review by experienced computing education instructors. The third research question was answered through solicitation, response, collection, and analysis of data from experienced computing education instructors. The fourth research question was answered by analyzing expert review data and making modifications to the web-based combined laboratory.

Relevance and Significance

Laboratory courses prepare students for employment in computing disciplines (Chao, 2010; Lahoud & Krichen, 2010; Uludag et al., 2012). Traditionally, local campus laboratory facilities provide hands-on learning opportunities for students who study in a residential campus environment. Non-traditional computing education students are an important sector of the student population, have unique academic challenges, spend little time in a residential campus setting, and need access to flexible web-based learning environments (Newman & Clure, 2012; Rao, 2012). The cost, flexibility, and access limitations of hands-on laboratories are driving a shift toward more affordable and flexible web-based laboratory alternatives, which are accessible to the growing non-traditional student population (Choi et al., 2010; Corter et al., 2011). Non-traditional student learning and motivation in web-based laboratory environments are not well understood. This study of an innovative web-based laboratory configuration extended understanding of laboratory components and guided effective laboratory designs (Konak et al., 2014; Lahoud & Krichen, 2010). Academic program leaders will benefit from the detailed findings and recommendations regarding best practices that guide the design of adaptable, practical, and usable laboratory environments for computing students.

Barriers and Issues

Implementation of the research required IRB approval from Nova Southeastern University (Appendix A). This project investigated the design and validation of an innovative web-based learning model in which the variables were not under control of the researcher. While IDMs are designed to function in a specific context, design and development research examines model development in a working environment (Richey &

Klein, 2007). Few design and development research projects have been undertaken in similar settings with non-traditional undergraduate students. Adult learner skills with online tools are not well understood (Kim & Frick, 2011). Additionally, universal metrics for measuring the effectiveness of web-based computing education laboratories are not available (Ma & Nickerson, 2006). The opportunities for pilot testing the model were limited. The findings were largely context specific and may not be readily generalizable outside of the local classroom learning environment (Richey, 2005). The researcher's previous experience as an instructor may have introduced presuppositions that affected interpretation of the data. The influence of the researcher, an experienced computing education instructor, possibly introduced bias into the analysis of the Delphi expert review panel data.

Definitions and Acronyms

Accreditation Board for Engineering and Technology (ABET): ABET is the accrediting body for institutions that seek accreditation for their computing education programs. Additionally, ABET provides guidelines for university computing programs (ABET, 2010).

ARCS Motivation Model: ARCS is a model developed by motivation theorist John Keller that aims to increase learner motivation through strategies that focus on Attention, Relevance, Confidence, and Satisfaction (Keller, 2010).

Combined Laboratory: A combined laboratory merges multiple laboratory formats to incorporate the benefits and mitigate the limitations of each format (Author).

Computer Based Learning (CBL): CBL is a modular learning modality available through a computer interface. Modularity and digital format allow for frequent assessment and scaffolding feedback (Green, 2012)

Delphi: The Delphi method was developed at the RAND Corporation to apply expert input in a systematic approach using questionnaires and controlled opinion feedback to guide understanding and decision making with respect to complex problems (Linstone & Turoff, 1975).

Non-Traditional Student: Non-traditional students are defined using a variety of qualities associated with class, gender, ethnicity, and age. Examples of non-traditional students are adult, first generation, single parent, and disabled (Field, Merrill, & West, 2012).

Summary

The remainder of this dissertation includes a review of literature, a description of the research methods, an overview of the results, and a summary of the conclusions. The literature review covers laboratory formats, roles, studies, and designs. A discussion of model development and motivation design methods is presented in the methodology chapter. The results of data collection and analysis are presented with findings from the study. Conclusions, implications, and recommendations are summarized at the end of the dissertation.

The literature review used a wide variety of sources related to laboratory format, purpose, and use. A discussion of recent laboratory research supplies a foundational understanding of laboratory use in variety of academic disciplines including computing education. Additionally, articles and studies related to instructional design of web-based models was synthesized with research concerning non-traditional student learning needs to provide an overview of issues related to web-based laboratory model design for non-traditional learners.

The methodology chapter provides a brief overview of the methodologies, design, instruments, and steps that were used to complete the research project. The chapter includes a brief discussion of the problem and goal of the study and proposed solution. A summary of the research design includes a description of design and development methodologies. The implementation of Delphi techniques are described for the internal validation of the web-based combined laboratory model.

Data analysis and findings are presented in the results chapter. Model development and validation provided rich data to guide an understanding of the results of the study. Design and development steps demonstrated that models can be created by experienced instructors with minimal resources. Internal validation of the model was analyzed using data from pilot studies and the Delphi expert review process.

The final chapter summarizes the conclusions, implications, and recommendations from the study findings. The outcome of model design and development, internal validation, and enhancement are discussed. The implications of the study for computing education designers, students, and leaders are presented with recommendations for future research.

Chapter Two

Review of the Literature

The literature review informs the reader concerning non-traditional student experiential learning in computing education laboratories. A summary of hands-on and web-based laboratories describes the principal computing education laboratory implementations. Insights into new laboratory settings come from an overview of recent developments. A survey of comparative research explains issues of learning and satisfaction between traditional hands-on laboratories and the emerging web-based designs. Finally, non-traditional learner needs are discussed in the context of web-based learning and computing education laboratory design.

Overview

The need for hands-on experiential learning in a laboratory environment is widely supported by the engineering, science, and computing education disciplines (Abdulwahed & Nagy, 2011; Corter et al., 2011; Konak et al., 2014). A necessary element of computing education, laboratories allow student discovery and practical experience through manipulation of real-world equipment. Laboratory experiences should increase learner understanding of course concepts, domain skills, and problem solving strategies (Chen, 2010).

Traditionally, laboratory activities have been conducted in a local campus setting in which students carry out experiments while collocated with the equipment. Local campus environments are known as *hands-on laboratories* because students can touch and manipulate tangible equipment (Ma & Nickerson, 2006). Hands-on laboratories are expensive to maintain and do not meet the needs of the growing number of non-traditional students who attend classes online and cannot participate in an on-campus laboratory class (Uludag et al., 2012).

Many institutions have explored web-based laboratories as a way to reduce costs and expand non-traditional learner access to laboratory facilities. Students enter web-based laboratory classes through the Internet and are remote from the experimental equipment. Simulation and remote laboratories have emerged as the primary implementations for web-based laboratory classes (Corter et al., 2011).

Web-based simulation laboratories use software rather than real experimental hardware to simulate laboratory experiments. Simulation is inexpensive, models real equipment, allows student control of the laboratory environment, and facilitates multiple observations of the experimental process (Rutten et al., 2012). Computing education students use simulation laboratories to practice experiments before moving to more complex laboratory systems. Simulation laboratories have been criticized for a lack of fidelity and oversimplifying the experimental environment (Abdulwahed & Nagy, 2011; Chen, 2010; Wolf, 2010).

Web-based remote laboratories allow learners to experiment in an authentic computing environment using real computer hardware and software with significantly lower operating expenses than hands-on laboratories (Uludag et al., 2012). Additionally, remote laboratories can be shared among multiple learners without temporal or physical restrictions (Wolf, 2010). Students manipulate the laboratory equipment remotely. Although remote laboratories use real equipment, critics are concerned that the learners do not gain the full benefit of experimental learning because they are not located with and physically manipulating the apparatus.

Abduwahed and Nagy (2011), Cano (2010), and Lahoud and Krichen (2010) suggested combining simulation and remote laboratories as a way to compensate for the individual weaknesses in each method. A *combined web-based laboratory* blends the benefits of simulation and remote laboratories into a single laboratory environment. Green (2012) proposed a web-based laboratory model that integrates computer-based learning exercises to reinforce laboratory objectives before moving into simulation and remote laboratory activities. This approach creates a constructivist environment that motivates students through self-paced iterative learning activities, scaffolding feedback, frequent reinforcement, and regular assessment (Jolliffe et al., 2012). While simulation has been beneficial in preparing students and remote laboratories offer flexibility, academics are skeptical that web-based laboratories can provide an acceptable level of learner achievement (Ma & Nickerson, 2006).

In a review of hands-on and web-based laboratory studies, Ma and Nickerson (2006) found that most were conducted in engineering disciplines and that few computing education studies were available. Additionally, the lack of standardized assessment metrics made relevant comparisons between hands-on, simulation, and remote laboratories difficult. To date, a consensus is lacking among researchers about what students should learn from laboratories in computing education disciplines.

A web-based laboratory design should consider the needs of learners, the priorities of computing technology stakeholders, the changing requirements of industry, and relevant information technologies (Choi et al., 2010; Green, 2012; Jolliffe et al., 2012). Learning style and self-efficacy are important considerations when planning online learning environments for non-traditional learners (Newman & Clure, 2012). Student managed activities, such as computer based learning modules offer exercises to build formative knowledge. Simulation programs afford rehearsal of complex laboratory activities, which increases confidence before performing challenging remote experiments (Green, 2012; Jolliffe et al., 2012).

Laboratories are expected to prepare computing education learners to fill job openings in industry (Choi et al., 2010; Uludag et al., 2012). In addition to technical skills, experiential learning should help students develop critical thinking and metacognitive abilities (Chen, 2010). Self-managed laboratory activities that afford independence and control of learning play a significant role in preparing computing education learners to succeed in a corporate technology setting. Laboratory design practices should be guided by an understanding of experiential learning roles in computing education programs and adapt to the needs of the student user population.

An important segment of the total undergraduate student population, non-traditional learners are over 25, work while attending college, support a family, and struggle with complex time management issues (Field et al., 2012; Rao, 2012; Rowan-Kenyon et al., 2010). Because schedule flexibility is important, many non-traditional students prefer to complete some or all of their classes in an online modality. These students seek the flexibility and control of web-based environments that include self-paced repetitive learning materials.

The Role of Laboratories in Computing Education

Data from laboratory experiments provide concrete insight into the limitations of theories introduced in the classroom and reinforce the framework of a technical discipline

(Corter et al., 2011; Konak et al., 2014). Wolf (2010) added that laboratory exercises increase learner experience in the practice of experimentation while providing an opportunity to work in real computing environments. Access to expensive real-world computing equipment prepares students for work in a corporate computing technology setting.

The pace of change in computing is unparalleled among technical disciplines of study, which contributes to the difficulty employers experience in hiring graduates with the appropriate skills to fill new job openings. Relevant laboratory exercises are needed to fully prepare students for new jobs (Choi et al., 2010). Lahoud and Krichen (2010) noted that experiential learning from laboratory activities provide an opportunity to develop the expertise demanded by industry. Computing education students use laboratories to gain hands-on skills, solve real-world problems, and gain a better understanding of technology concepts (Chao, 2010).

Corter et al. (2010) proposed laboratory experiences as a way to increase student understanding and application of learning materials. Laboratories reinforce the conceptual framework of a technical discipline (Lahoud & Krichen, 2010). Wolf (2010) suggested a goal of laboratory instruction is to increase learner experience with theory and practice through experimentation. He noted that exposure to potential problems and failures are an important feature of a laboratory education. Cautioning that laboratory training is not just about learning concepts and skills, Chen (2010) proposed increasing learner aptitude for inquiry through experiential activities. Green (2012) identified student discovery as an important component of computing education provided by laboratory exercises. Laboratories help educators meet the challenges of preparing computing education students to handle complex technical problems (Uludag et al., 2012).

Hands-on Laboratories

Hands-on laboratories require dedicated on-campus facilities and entail investigation with real equipment (Cano, 2010). The required equipment is set up in the laboratory and the learner is physically present (Ma & Nickerson, 2006). The sense of realism existing in hands-on laboratories supports higher level learning. Abdulwahed and Nagy (2012) noted that fidelity and realism lead to better hands-on skills and equipment awareness. Proponents of hands-on laboratories suggest important outcomes of technology learning, such as the ability to configure equipment and recognize theoretical system limitations can only come from physical presence, observation, and manipulation of the experimental equipment (Chen, 2010). Others suggest that significant limitations of cost, complexity, flexibility, and access limit the effectiveness of hands-on laboratories (Cano, 2010; Chao, 2010; Choi et al., 2010; Uludag et al., 2012; Wolf, 2010; Xu et al., 2010).

The high cost of hands-on laboratory facilities results from a combination of maintenance, personnel, and equipment expenses (Cano, 2010; Wolf, 2010). Infrastructure, space, and human resources were described by Cano (2010) as driving the high cost of campus laboratory facilities. Wolf (2010) advised that setting up a realistic hands-on laboratory environment is a complex and time-consuming task. Academic institutions have difficulty maintaining the complexities of a computer environment that constantly changes (Xu et al., 2012). Uludag et al. (2012) noted that the management of a hands-on laboratory is hampered by extensive maintenance needs, rapid equipment obsolescence, and space limitations.

The finite space available restricts efficient use of hands-on laboratories. Accessible laboratory space is limited, which affects scheduling, flexibility, and access. Describing the difficulty of reconfiguring laboratory equipment, Chao (2010) suggested hands-on laboratories lack the flexibility needed for different computing education disciplines to share the same physical laboratory space. Choi et al. (2010) noted hands-on laboratories are often not available to non-traditional distance learners who access class via the Internet. Learners must reserve laboratory space well in advance and have limited time with the equipment. Hands-on laboratory scheduling limitations restrict pre-laboratory practice and multiple runs of experiments (Cano, 2010).

Students like the feeling of presence in hands-on laboratories (Cano, 2010). Studies suggest that working with real equipment and the high levels of realism with hands-on laboratories enhances learning (Abdulwahed & Nagy, 2011). Other studies advise learning is an iterative process that takes time. Access to a hands-on laboratory is too restrictive to provide learners with the time needed to fully develop knowledge. The limitations of cost, flexibility, and access have promoted the development of web-based alternatives (Lahoud & Krichen, 2010).

Web-Based Laboratories

Technology-enabled learning environments can free students from the restrictions of traditional education, which takes place at institutions with classrooms in a fixed location where learning occurs synchronously in time and space. Wedemeyer (1981) encouraged the use of whatever non-traditional learning format is needed to meet learning goals. Web access to learning is an important option for busy non-traditional students who may not be able to attend class on campus in a traditional setting (Green, 2012). Corter et al.

(2011) suggested that in addition to convenience, web-based laboratories can be justified by cost, space, and time efficiencies. Web-based simulation and remote laboratory options are convenient for students and eliminate the need to attend a laboratory course in a physical space.

Web-Based Simulation Laboratory

Simulation laboratories are tools that model real-world equipment and simulate experimental conditions on a personal computer or via the Internet (Abdulwahed & Nagy, 2011). Simulation laboratories contain a system model and have been used effectively in science education to enhance traditional instruction by increasing visualization of complex concepts (Rutten et al., 2012). Cano (2010) described a simulation laboratory as consisting of computers running experiments with software that reproduces the operation of real experimental equipment. Simulation laboratories allow students to collect data from a model that illustrates course concepts, provides a visual demonstration of an experiment, and tests learner knowledge (Corter et al., 2012; Green, 2012).

Through simulation learners can explore a variety of experimental situations in a systematic way with a simplified version of a complex system that allows practice, problem solving, and event manipulation (Rutten et al., 2012). Abdulwahed and Nagy (2011) noted simulation laboratories accommodate different learning styles and allow repeated experiments in a flexible learning environment that supports iterative learning. Sarkar and Petrova (2013) suggested that students are more engaged in computing education classes complemented with simulation laboratories to assist in learning course objectives. The learning support and scaffolding provided by simulation can improve learner performance (Wolf, 2010). Simulations place emphasis on the learner as an active participant in knowledge acquisition, which facilitates relevant inquiry, question formulation, data development, and hypothesis evaluation skills (Driscoll, 2005). Inexperienced learners respond to simulation laboratories that offer knowledge building and self assessment tools with an intuitive easily manipulated interface.

Although simulation laboratories do not take up space and have relatively low cost compared to other laboratories, many argue the lack of realism contributes to poor skills with real equipment (Abdulwahed & Nagy, 2011; Cano, 2010; Wolf, 2010). Ma and Nickerson (2006) cautioned that despite the advantages of simulation, it is important to remember it is not real. Corter et al. (2011) reported that some argue simulations cannot replace hands-on laboratories for introductory courses. Chen (2010) warned simulation designs often oversimplify the experimental environment allowing learners to develop a naïve view of scientific concepts. Additionally, because web-based simulation laboratories are run remotely from the instructor, feedback may be limited (Abdulwahed & Nagy, 2011). The limitations of fidelity suggest simulation laboratories alone do not meet the full scope of learner needs.

Web-Based Remote Laboratory

Remote laboratories consist of real experimental equipment managed through a web interface (Abdulwahed & Nagy, 2011; Corter et al, 2011; Cano, 2010; Ma & Nickerson, 2006; Wolf, 2010; Xu et al., 2012). Although the learner is not physically present with the equipment, remote laboratories provide a secure, flexible, and adaptable environment for experiential learning (Chao, 2010; Uludag et al., 2012). Students can perform experiments while operating fully-functional computing equipment, and gather data independently on their own schedule. Remote laboratories in computing education provide an authentic environment similar to an operational corporate computing environment with servers, routers, and security hardware. Learners can complete the same tasks in a remote laboratory that corporate system administrators perform while maintaining operational computer networks. Remote laboratories are emerging to address cost, flexibility, access, and maintenance issues (Wolf, 2010).

It is widely recognized that remote laboratories offer significant savings through a reduction of the space, personnel, and maintenance required by hands-on laboratories (Cano, 2010; Chao, 2010; Corter et al., 2011; Burd et al., 2009; Uludag et al., 2012; Wolf, 2010). In a study of a remote laboratory established to facilitate mobile computing, Burd et al. (2009) described a $90 thousand dollar cost advantage over a traditional hands-on laboratory achieved through reduced space and personnel requirements. Using cloud computing technology to reduce the time and complexity of laboratory management, Chao (2010) implemented a remote laboratory at one-third the cost of a hands-on laboratory. In addition to cost savings remote laboratories are accessible to more students. Available to distance and local learners, remote laboratories can also be shared among many students at different universities (Abdulwahed & Nagy, 2011; Cano, 2010; Wolf, 2010). With flexible, configurable settings, a single remote laboratory can represent a wide range of computing environments for experimentation (Xu et al., 2012). Remote computing education laboratories allow students to practice with the expensive hardware and software products used in corporate computing environments (Green, 2012).

A significant disadvantage of a remote laboratory is the lack of direct experience with computer hardware (Uludag et al., 2012). Some real-world activities, such as troubleshooting and installing hardware components cannot be completed in a remote laboratory environment. Additionally, Burd et al. (2009) and Xu et al. (2012) noted that distance learners in a remote laboratory setting must overcome technical complexity. Novice learners with limited technical background can be overwhelmed by the complexities of a remote laboratory. Remote laboratories can experience concurrent use limitations and are not available without an Internet connection. When implementing a remote laboratory environment, institutions face configuration, operation, and administration challenges. Although remote laboratory costs are lower and access to facilities increased it is unclear if student learning is achieved (Wolf, 2010).

Web-Based Combined Laboratory

Hands-on, simulation, and remote laboratories when used alone have difficulty providing a full range of experiential learning opportunities (Abdulwahed & Nagy, 2011). Combining simulation with other methods has been suggested as a way to create a web-based laboratory environment that more fully aligns with learner's experiential learning needs (Cano, 2010; Corter et al., 2011; Green, 2012). A web-based combined laboratory provides several modes of laboratory experimentation within a uniform software environment, which allows learners to build knowledge by progressing through increasingly difficult activities at their own pace. Green (2012) suggested a web-based laboratory that merges computer-based learning with simulation and remote laboratories to create a combined laboratory environment. The use of cloud technology would accommodate multiple configurations for a variety of computing education disciplines with minimal reconfiguration complexity (Chao, 2010).

Web-based laboratories have raised doubts. Educators question if an effective learning experience can be delivered in a web-based environment (Wolf, 2010). Corter et al. (2011) expressed the concern that economic considerations may overshadow issues of learning effectiveness. Chen (2010) suggested unsophisticated reasoning skills can result from oversimplified web-based simulations. Doubts about the educational value of web-based laboratories are exacerbated by the lack of agreement about what laboratories should teach students. The effectiveness of web-based laboratories is rarely compared with hands-on laboratories in computing education disciplines (Ma & Nickerson, 2006).

Laboratory Studies

Computing education researchers are concerned with the lack of systematic studies of learning outcomes in web-based laboratories. Few studies have been undertaken to compare learning outcomes between hands-on, simulation, and remote laboratories. Ma and Nickerson (2006) observed that most comparative research occurs within the engineering disciplines. Corter et al. (2011) noted that well designed evaluation studies of technology based laboratories are needed to examine behavioral, attitudinal, and outcome measures in the context of the educational objectives of the laboratory.

In their review of comparative laboratory studies, Ma and Nickerson (2006) suggested a common set of standards were needed to assess the effectiveness of engineering education laboratories. They proposed adopting the standards for conceptual understanding, design, social, and professional skills established by the Accreditation Board of Engineering and Technology (ABET, 2010). Computing education laboratory studies would benefit from a similar approach.

Two recent large scale comparative studies within engineering disciplines provided insight into relevant issues between hands-on and web-based laboratories. Abdulwahed and Nagy (2011) compared the achievement of undergraduate chemical engineering students who had only a hands-on laboratory experience with similar students who experienced a combination of simulation, remote, and hands-on experiments. Students who did not have simulation and remote laboratory preparation for the hands-on laboratories had lower performance on tests as the semester progressed. Students who had both simulation and remote preparation had significantly higher achievement. Abdulwahed and Nagy (2011) concluded that hands-on laboratories supported with a laboratory manual are most suitable for students with a read-write learning style, whereas combined simulation and remote laboratories used with the laboratory manual adapted the hands-on laboratory to the needs of students with visual and kinesthetic learning styles.

Corter et al. (2011) compared the effectiveness of hands-on, remote, and web-based simulation laboratories with regard to individual and group learning outcomes in a mechanical engineering class. Three laboratory sections completed two laboratory experiments using the same format, either hands-on, simulation, or remote for each experiment. They concluded that students can learn effectively in all three laboratory environments and noted no significant difference in the conceptual knowledge tests between students using the three laboratories. Additionally, Corter et al. (2011) suggested that “social and motivational factors appear to be more important than the simple physical form of the lab apparatus and interface in determining learning effects” (p. 2065).

Many studies of remote computing education laboratories provided a qualitative view based on surveys seeking a self-reported appraisal of learning from students. Wolf (2010) suggested a quantitative perspective is needed. He proposed investigating if students learn while using a web-based laboratory.

In an assessment of learning in lectures compared to learning in remote laboratory activities, Wolf (2010) studied the outcomes of 29 computer networking students. He compared student knowledge prior to the lecture, after the lecture, and after a remote networking laboratory. Using the same questions for each assessment Wolf (2009) inferred progression of student learning before and after the lecture, and laboratory events. A *triple* method was used to measure each student on each test question to determine if the student answered the question correctly, did not answer the question correctly, or did not participate. Wolf (2009) concluded that definite learning occurred in both lecture and laboratory assessments at nearly the same level. He noted that lectures and laboratories are equally important. The most learning occurred with novice learners who had one or fewer prior networking courses.

Concerned that the literature focused too much on the technical aspects of web-based laboratory design, Konak et al. (2014) examined the pedagogical characteristics of an information security laboratory course. Experience using only step-by-step laboratory instructions to guide students through complex experiments yielded inconsistent competency and motivation. Kolb’s Experiential Learning Cycle (ELC) was proposed as a framework to improve student learning outcomes compared to outcomes in previous step-by-step engineering laboratory studies. Comparing the inquiry-based design with a laboratory using prescriptive step-by-step instructions, the researchers concluded that students who completed experiments with the ELC design had higher levels of competency development and interest.

Using a web-based network simulation tool that included tutorials, models, and quizzes, Sarkar and Petrova (2013) observed that inexperienced learners respond to systems that facilitate knowledge building and self assessment tools. They noted that once foundational knowledge is gained a more sophisticated tool can be used. Sarkar and Petrova (2013) concluded that the use of a simulation laboratory increased student knowledge and comprehension in an introductory networking class.

In a study of traditional student achievement in an information and communication engineering course, Cano (2010) used a simulation laboratory to prepare students for a hands-on laboratory experiment. Students were offered the option to prepare for a hands-on experiment with a simulation laboratory. The participants in the study were 59 students who opted to use the simulation laboratory. The results indicated that students who used simulation to prepare for the hands-on laboratory experiment performed better on the assessment than students who did not use simulation. Cano (2010) concluded that the simulation laboratory helped students develop a deeper understanding of the topic and the laboratory experiment. She observed that motivation increased by varying the laboratory activities. The use of simulation laboratories may be a way to compensate for the shortcomings of hands-on laboratories. Noting that additional tasks with simulation can facilitate student self-learning, Cano (2010) suggested simulation laboratories be used to prepare learners for hands-on laboratories.

In a comparative study of hands-on, simulation, and remote laboratories, Lahoud and Krichen (2010) assessed the influence of individual characteristics of non-traditional computing education learners on their laboratory preferences. Using surveys to gather participants' demographic and preference data, they assessed the effect of major, work experience, and number of online classes taken with respect to a preference for either a hands-on, simulation, or remote laboratory environment. Learners preferred hands-on laboratories over simulation and remote laboratories. Students with majors in computer networking fields had higher satisfaction with hands-on laboratories, whereas students in general information technology classes had higher satisfaction with remote and simulation laboratories. Lahoud and Krichen (2010) noted the results suggested a dual learning path; students with more experience benefited most from hands-on and remote laboratories, while simulation and hands-on laboratories were more effective for inexperienced learners who plan to major in networking. They concluded that students are more engaged in computing education classes complemented with simulation resources to assist in learning course objectives. Additionally, experiential and learning style differences can affect learner satisfaction and performance with computing education laboratories. Non-traditional learners considered access to the laboratory environment more important than usability and fidelity.

Well designed studies are needed to assess the effectiveness of hands-on and web-based computing education laboratories. Such research will benefit from common standards that support consistent assessment between laboratory types in meeting computing education objectives. Computing education disciplines can benefit from the lessons of comparative engineering laboratory studies, which indicate students can learn effectively in all three laboratory environments and combinations of simulation, remote, and hands-on laboratories lead to higher achievement.

Computing education laboratory studies described important outcomes regarding the application of web-based laboratories. Several studies reinforced the value of simulation laboratories in preparing students for more complex laboratory activities. Learning with remote laboratory exercises was demonstrated in a blended classroom environment (Wolf, 2009). Learners increased knowledge and comprehension when using web-based simulation laboratory in an introductory networking class (Sarkar & Petrova, 2013). Students who used a simulation laboratory to prepare for an information and communication engineering laboratory class performed better on the learning assessment than students who did not use simulation (Cano, 2010). In general, non-traditional learners preferred hands-on over other laboratories. A dual learning path was indicated for non-traditional learners, which suggested those with more experience benefitted from a combination of hands-on and remote, while less experienced learners benefitted most from a blend of simulation and hands-on laboratory experiences (Lahoud & Krichen, 2010). Additionally, non-traditional learners consider access more important than usability and fidelity. The outcomes of these studies provide insight into web-based laboratory design based on observed user preferences and experiences.

Web-Based Laboratory Design for Non-Traditional Learners

Relevant web-based laboratory designs must align with learner's needs and goals (Green, 2012; Joliffe et al., 2012). Non-traditional learners bring a unique challenge to web-based laboratory design. Unlike traditional students who enter a residential university immediately after high-school and graduate within six years, non-traditional adult students typically work directly after high school, start college later, and take more than six years to graduate (Boston & Ice, 2011; Rao, 2012). Non-traditional online learners are the fastest growing segment of university students (Rowan-Kenyon et al., 2010). The Center for Education Statistics (2011) predicts that non-traditional student enrollment will grow by 16% in the next decade.

Non-traditional students are defined using a variety of qualities associated with class, gender, ethnicity, and age (Field et al., 2012). Examples of non-traditional students are adult, first generation, single parent, and disabled. Non-traditional students include those for whom English is not the first language and adults returning to community college (Newman & Clure, 2012). Learners who live in remote locations are culturally and linguistically diverse, and adults returning to college for certification or degrees are all considered non-traditional students (Rao, 2012). When designing web-based laboratories, it is important to understand how non-traditional learners see themselves as students. Non-traditional students may not have experiences in their previous cultural environments that support integration into a higher education setting, whereas some qualities of non-traditional students, such as persistence, do support success in college.

Learning style and self-efficacy are associated with non-traditional student use of online systems and successful outcomes (Newman & Clure, 2012). Computing self-efficacy is an important factor for users in multimedia and online supported learning environments. Non-traditional students consistently self-reported high ability with general technology tools. Self-reported computer self-efficacy has little relevance. Adult learner outcomes based on the use of technology in Science, Technology, Engineering, and Math (STEM) disciplines is affected by learning style. Students with different learning styles use multimedia-based STEM tools differently. Sarkar and Petrova (2013) observed that inexperienced learners respond to simulation laboratories that offer knowledge building and self assessment tools in a simple, intuitive user interface.

Newman and Clure (2012) reported that non-traditional students prefer computer based formative exercises that allow them to self evaluate progress.

Rao (2012) described non-traditional learner challenges of ambiguity of expectations, resistance to text base learning, isolation, and technology. Ambiguity can be lessened by open communication between instructor and students, consistent use of the learning management system, and a clear syllabus and rubrics. Problems with text based learning resistance can be mitigated by offering options for multimodal sources, digital and audio texts, and alternate ways to demonstrate knowledge. Isolation can be reduced through periodic synchronous meetings and frequent short assignments with timely feedback. Peer assistance and proactive technical support that is always available can mitigate technical problems.

In describing Universal Design (UD) guidelines for non-traditional learners, Rao (2012) reminds designers that web-based designs should account for the backgrounds, characteristics, and needs of diverse students. Text-based courses present a challenge for students who are not native speakers. Additionally, distance classes may result in feelings of isolation, misunderstanding of social context, and technical difficulties. A technology rich online environment can accommodate for issues of mobility, sensory, and learning challenges. An awareness of communication styles, authentic learning activities, and inclusive collaboration is necessary to support adult learner preferences.

Wedemeyer (1981) suggested early that education technology facilities would be able to reach non-traditional learners where they are, when they have time, and at their convenience. He reminded educators that communication between teacher and learner can occur successfully across distances when the educator employs technology in a process of teaching rather than simply using it as a tool. Wedemeyer (1981) noted adult learners move in and out of the learning environment as needs and motivation dictate, are more interested in problem solving and application of knowledge, and want to learn in the environment where they live and face problems. Non-traditional adult students are more mature, work independently, and are capable of managing their needs, time, and decisions. In describing a vision of technology in education, Wedemeyer (1981) proposed course design be completed from a humanist perspective that ensures the non-traditional learner is accepted in his or her environment. Asynchronous web-based programs are very convenient and appealing to non-traditional students who may be disabled or balancing school with a job and family responsibilities. These learners are attracted to the flexibility of not attending class in a residential campus setting.

Web-based learning, also known as online learning, takes place over the Internet. The Internet is an immense collection of independently owned private networks accessed using a computer with a web-browser. Internet access is provided by an Internet Service Provider (ISP). Most learning materials are available through a subset of the Internet known as the World-Wide-Web (WWW) or simply the *web* (Jollife et al., 2012). A web-browser is required to access material on the web. The web provides rich content for building and delivering course material. Jollife et al. (2012) cautioned that the use of the web for learning is not an assurance of an effective learning environment; web-based learning must be based on superior learning principles and theory rather than the vast supply of content available on the Internet.

New laboratory formats often are developed by individual instructors outside administrative controls and are not rigorously assessed for learning effectiveness (Corter et al., 2011). Uludag et al. (2012) suggested that work in science and engineering supported by laboratory activities can guide computing education laboratory design. Web-based laboratory design should consider the different roles of computing technology players, the changing priorities of industry stakeholders, and relevant emerging technologies (Choi et al., 2010). Well chosen laboratory activities will help students understand abstract technical concepts and theories (Corter et al., 2011). A learn by doing laboratory method exposes learners to real-world problems and builds skills sought by employers. Uludag et al. (2011) proposed intensive remote laboratory exercises to foster comprehension, application, synthesis, and evaluation of learners' skills.

Green (2012) proposed applying the Keller (2010) ARCS model of motivation as a framework to design a web-based laboratory that combines computer based learning, simulation, and remote laboratory activities around weekly learning objectives. A combined laboratory increases learner perceptual arousal by varying assignments. Joliffe et al. (2012) noted that a combined environment uses multiple approaches to deliver material and communicate with learners over the web. The web is well suited for implementing a learning environment that allows students to manage their own progress. Green (2012) advised that students prefer control over the pace of work and choose to schedule laboratory times when they are most attentive.

Setting clear objectives, giving frequent feedback, and providing multiple assessments to demonstrate success build learner confidence (Green, 2012). Learner satisfaction comes from the ability to apply newly acquired knowledge. Xu et al. (2012) suggested motivation results from clear grading criteria and the relevance of laboratory assignments. While noting that web-based laboratory experiments should illustrate theoretical concepts, Green (2012) suggested that the varied learning resources in a combined laboratory prepare students to solve relevant problems with real computing systems used in corporate environments. Creativity results from student research in a flexible environment that facilitates experimentation (Xu et al., 2012).

Learner assessment is an important element of web-based laboratory design (Joliffe et al, 2012). Green (2012) suggested frequent assessment is needed to provide learner feedback, build confidence, and monitor student progress. A web-based combined laboratory that includes computer based learning, simulation, and remote laboratory activities, provides frequent opportunities for formative and summative assessments. Quizzes associated with computer based learning modules offer opportunities for formative assessment and scaffolding feedback. A simulation laboratory allows rehearsal and confidence building (Driscoll, 2005). A student's final laboratory reports of experiments conducted in a remote laboratory provide summative assessments of the laboratory experience (Green, 2012; Joliffe et al., 2012).

A web-based laboratory design must be appropriate to the learner and the material. Joliffe et al. (2012) and Sarkar and Petrova (2013) suggested that web-based learning designs be based on the constructivist principle that knowledge and understanding are gained actively through personal experience and experiential activities. Web-based laboratories should facilitate acquisition of foundational knowledge to support learning for students with a range of prior experience and knowledge. Learning must focus on relevant problem-based scenarios and the use of technical resources. Asynchronous web-based learning environments are convenient for non-traditional learners who prefer computer-based formative exercises that allow self-evaluation. A model that describes the phases of a systematic and iterative process will begin with a description of the objectives and end with a summative assessment (Jolliffe et al., 2012).

Chapter Three

Methodology

Overview

The goal was to design, validate, and enhance a web-based laboratory instructional design model (IDM). IDMs assist with matching the learning process with the context (Branch & Kopcha, 2014). Clearly defined models describe the application of procedures to the development of specific teaching and learning materials. Instructional designers and instructors use IDMs as conceptual tools to visualize, direct, and manage the creation of teaching and learning materials. Models work best when matched with the corresponding context (Richey, 2005). The research focused on model development, validation, and use (Richey & Klein, 2014).

Models can vary in philosophical direction or theoretical orientation. Richey (2005) identified two major types of models, conceptual and procedural. Conceptual models identify variables that affect the design process and explain how they are interrelated. Procedural IDMs are derived from general systems theory and describe the steps in model design.

A web-based combined laboratory model was developed using procedural design methods. The procedural design process began with analysis activity, proceeded through specification of the learning environment to the development of components. Design and development research methods guided validation of the model with respect to the development process, components, and use (Branch & Kopcha, 2014; Gibbons, Boling & Smith, 2014; Richey & Klein, 2014). Richey (2005) noted a model's validity is linked closely to how well it meets the intended context.

Validation was a natural part of the design process and was continued at every stage of development including implementation (Richey, 2005). Validation is comprised of both internal and external validation methods. The study centered on the internal validation of the model's components.

Internal validation using pilot studies and expert review techniques confirmed the integrity of the model and its use, (Richey & Klein, 2014). Validation included a precise description of the components, systematic data collection concerning application, and addressed discrepant data through repeated reviews (Branch & Kopcha, 2014). As expected the study did not provide concrete answers to problems; it did uncover innovative applications of the model and important issues to guide future research (Richey & Klein, 2007).

The development process resulted in a web-based combined laboratory that integrated computer based learning, simulation, and remote laboratory components. Comprehensive internal validation steps extended understanding by examining the model in a variety of situations including alternative settings, different types of learners, novice and expert designers, diverse content areas, and assorted delivery strategies. The research developed new knowledge in the form of an enhanced and innovative laboratory model (Richey & Klein, 2007).

Research Design

The study addressed model development, validation, and enhancement of a web-based combined laboratory model using design and development research methods (Richey & Klein, 2014). Design and development research is associated with the instructional design and technology discipline focusing on IDMs, tools, and products (Richey, 2005). It is applied research conducted with a real-life perspective within a specific context and population. Instructional design research examines model development, validation, and use.

A comprehensive literature review was conducted to provide an overview of web-based laboratory studies in higher education prior to model design and validation. The review described the role of laboratories in computing education, summarized different laboratory formats, and examined issues of web-based laboratory design for non-traditional learners. The benefits and drawbacks of various formats were discussed. Examples of web-based laboratories in a variety of disciplines were evaluated to develop an in-depth understanding of current implementations and areas where further research may be needed (Richey & Klein, 2007). The review of recent studies shed light on how different web-based laboratory designs were used to enhance learning.

Model Design and Development

Model design followed an Analysis, Design, Development, Implementation, and Evaluation (ADDIE) procedural design process (Richey & Klein, 2014; Branch & Kopcha, 2014). The web-based combined laboratory model was developed to address the experiential learning challenges of non-traditional students in undergraduate computing education programs. The development process included the integration of computer based learning, simulation, and remote laboratory components (Green, 2012).

Analysis was informed by the literature review and took place in the context of non-traditional student needs. It included an operational perspective to understand the instructional design requirements of computing education instructors. The analysis context was guided by a course structure in which non-traditional students spend little time on campus and complete a significant part of their learning in a self-directed format outside of class.

Design was guided by Keller's (2010) ARCS model of motivation. The design implemented strategies to ensure attention, relevance, confidence, and satisfaction were attained. Motivational strategies were integrated into the laboratory components to address challenges with learner attitudes, abilities, knowledge, and entering skills in self-paced learning environments. The laboratory was designed for implementation by novice or experienced instructors in a variety of computing education courses using existing resources (Richey & Klein, 2007). It was intended as either a stand-alone tool under control of the learner or for use in the classroom under instructor direction.

Development of the model followed the Green (2012) web-based combined laboratory framework. The components included objectives, computer based learning, simulation, and hands-on exercises. The model was adapted to incorporate existing content and resources (Branch & Kopcha, 2014).

Implementation of a database design laboratory prototype supported the initial pilot studies of model components, which provided formative revisions and internal validation of laboratory processes (Richey & Klein, 2007). It helped confirm the completeness, organization, and flow of laboratory components.

Evaluation followed a rigorous internal validation of the model. The evaluation process included the pilot studies and expert review by a panel of higher education computing instructors through an expert review process. Internal validation and model enhancement was the product of input from the panel.

Validation

The need for model research and validation is a significant concern in the instructional design community (Richey & Klein, 2007). Traditionally models gained validity through use and adoption by practitioners to meet specific needs (Branch & Kopcha, 2014). A more rigorous internal validation approach was implemented to provide an accurate description of the model using systematic data collection concerning the components and instructional applications. Internal validation is the process of collecting and analyzing data to demonstrate the effectiveness of a model or provide support for the components of a model. It examines the content and face validity of a model. Internal validity steps are taken during model development and guide design corrections.

Validity was examined from the perspective of higher education computing instructors and students. The internal validation process confirmed the integrity of the model components. The effectiveness of the components was established through pilot studies and an expert review process (Richey & Klein, 2007).

Over a period of approximately 14 months three separate pilot tests examined the completeness and sequencing of the components. The pilot studies implemented a database design laboratory in local campus database concepts courses to validate the model components. The database design laboratory included four units, each covering a single learning objective (Appendix B). Each unit included computer based learning, simulation, and an experiential learning exercise. One unit was presented each week for four weeks.

Expert review techniques extended the validation results of the pilot tests (Richey, 2005). Opinions regarding policy and best practices are often sought from experts in education contexts (Clayton, 1997). Group methods provide a better chance to get at the truth by providing multiple perspectives and an improved representation of stakeholder positions. While several expert consensus methods exist, the Delphi technique offers the advantage of participant anonymity, which avoids the direct confrontation of experts, is conducive to independent thought, and aids in the gradual formation of a consensus opinion (Okoli & Pawlowski, 2004). A diverse panel of experienced computing instructors was selected to provide a range of perspectives of instructional strategies, classroom settings, and expertise. The panel reviewed the adaptability, practicality, usability, and motivation design of the model under typical conditions, in a range of settings, by both novice and expert instructors (Richey, 2005).

The Delphi Process

The classic Dalkey and Helmer (1963) definition described the Delphi process as “a method used to obtain the most reliable consensus of opinion of a group of experts by a series of intensive questionnaires interspersed with controlled feedback” (p. 458). Delphi techniques facilitated the consensus of experienced computing instructors regarding the adaptability, practicality, usability, and motivation design of the model.

The process afforded a better understanding of the design context of the web-based combined laboratory model and identified potential curriculum issues (Clayton, 1997). It was part of a larger effort to design, validate, and enhance the model (Hasson & Keeney, 2011). The opinions of computing instructors from a variety of disciplines with different levels of experience contributed best practices to the design, validation, and enhancement process.

The iterative nature of the Delphi process allowed participants to think critically and generate data that informed modifications to the laboratory design to improve adaptability, practicality, usability, and motivation from the instructor's perspective (Linstone & Turoff, 1975; Okoli & Pawlowski, 2004). Incremental adjustments to the model were applied after each round of the Delphi based on expert recommendations. A revised model was promulgated at the beginning of each new round. Issues of adaptability, practicality, usability, and motivation guided subsequent Delphi review and model revisions.

Panel Selection

The Delphi method requires a panel of experts on the subject under study (Clayton, 1997). Expertise is the goal for panel selection and sets Delphi apart from other forms of survey research. The panel selection process is important to the success of the Delphi method. Okoli and Pawlowski (2004) consider expert selection the most important step in the Delphi process. In choosing a panel Clayton (1997) recommended using a selection process that allows highly qualified candidates to become evident.

A demographic survey provided comprehensive information concerning the experience of Delphi panel candidates in the context of the study environment (Appendix C). Purposeful sampling techniques were used to select a panel that reflected variety in computing education experience, disciplines, and delivery formats. Email, social media and recommendations from colleagues were the solicitation mediums.

Panel size was based on the desire for a diverse panel composition. Panel sizes vary between five to ten members taken from a heterogeneous population to 15-30 members from a homogeneous population (Clayton, 1997). A well composed Delphi panel will yield rich descriptive data based on a variety of relevant participant experiences. A heterogenous panel of approximately 10-14 members was the target of this study to compensate for the possible loss of participants during the six week Delphi process (Clayton, 1997; Okoli & Pawlowski, 2004).

Over one thousand solicitations were sent to computing professionals in search of higher education instructors (Appendix D). The result was 39 completed demographic questionnaires; 14 instructors were selected to participate in the panel. Five members were recruited through direct email invitations. Online communities of computing professionals also yielded five panel members. An email solicitation to Nova Southeastern University alumni resulted in two participants and two members were recruited as a result of colleague recommendations. One participant dropped prior to the end of round one due to workload conflicts leaving 13 panel members remaining.

Consensus

Criteria were established to describe results that indicated consensus (Clayton, 1997). A clear understanding of consensus guides rigor in the Delphi process (Okoli & Pawlowski, 2004). Consensus is often implied by a majority agreement to the questionnaires (Hasson & Keeney, 2011). While little explicit guidance is available in the literature regarding consensus, Hsu and Sandford (2007) offered several definitions of consensus ranging from a stability of responses to a predetermined percent of votes within two categories on five point Likert scale. Consensus was assumed when at least 10 members responded to the questionnaire, the central tendency of responses was stable over two rounds, 70 % or more responses rated three or higher, and the median score was higher than 3.25 (Clayton, 1997; Hasson & Keeney, 2011; Hsu & Sandford, 2007).

Delphi Rounds

The general Delphi process involved three phases or rounds of questioning (Clayton, 1977; Linstone & Turoff, 1975; Hsu & Sandford, 2007). During each round the participants reviewed descriptive materials related to the current model and provided feedback through a questionnaire. The researcher collated responses and provided every member of the panel with a statement of the collective position (Hsu & Sandford, 2007). Additionally a summation of comments from the previous round made every participant aware of the range of opinions and the reasons underlying those opinions. The model was revised after each round based on panel recommendations. The process was continued until the panel reached the desired level of consensus in round three. A three round Delphi is considered typical (Clayton, 1997, Hsu & Sandford, 2007).

Round One commenced with an information email that included the panel instructions, a link to the Survey Monkey questionnaire, and laboratory review materials (Appendices E and F). The participants completed the questionnaire and provided numerous comments regarding the model components in the context of adaptability, practicality, usability, and motivation design (Appendix G). Round One was completed by 13 participants.

The round one questionnaire used a simple yes/no format with comment fields to identify key issues in which consensus was needed. The researcher organized comments according to the context. The questionnaire responses and feedback were used to develop a statement of collective opinion and identify enhancements to the model.

Round Two was initiated after the round one data were reviewed and organized. The Round One Review Material was updated with enhancements recommended by panel members in the questionnaire. The Round Two instructional email included the Round Two questionnaire link (Appendix H). The updated review material and Round One comments were attached to the instructional email (Appendices I and J).

The Round Two questionnaire used a five point Likert scale and included comment fields (Appendix K). The researcher organized comments according to context and determined the Round Two level of consensus. The Round Two Review Material was updated with enhancements recommended by the panel.

Round Three began after the Round Two questionnaires were all in and the data reviewed and organized. The Round Two Review Material was enhanced with panel recommendations. The Round Three panel information consisted of the informational email with the questionnaire link (Appendix L). The Round Two panel comments and revised review material were attached to the informational email (Appendices M and N).

A five point Likert scale was used in the Round Three questionnaire (Appendix O). The questionnaire comments and feedback were collected and reviewed (Appendix P). The level of consensus between Rounds One, Two, and Three were compared (Appendix Q). Final enhancements were made to the model based on panel questionnaire responses and feedback (Appendix R). The Delphi panel process was closed and an email was sent thanking the panel members for their inputs to the study.

Instrumentation

Surveys and questionnaires are helpful for collecting demographic data and perceptions, which adds depth to data collection. Demographic survey and Delphi panel questionnaire instruments were used to gather data during the internal validation process (Appendices C, G, K, and O). Demographic data associated with candidate experience was collected to support Delphi panel selection (Hasson & Keeney, 2011). A series of questionnaires were used during the Delphi process (Clayton, 1997; Hsu & Sandford, 2007). The Round One questionnaire was used to identify critical topics in which consensus was needed. Questionnaires in the subsequent rounds gathered data to inform the consensus process.

Surveys can be used to gather information in a wide variety of formats and often are used to gather demographic information about participants and their skills (Rogers, Sharp & Preece, 2011). The brief one-page survey collected data to ensure Delphi panel members had the requisite knowledge and experience to address the research goals (Richey & Klein, 2007) (Appendix C). Information about candidates' highest degree, primary computing education discipline, type of institution, years of teaching, primary teaching format, and experience with laboratories supported panel selection. The demographic survey format used in this study was validated in 2013 by the researcher during a study completed for a human computer interaction course (Rogers et al., 2011; Shneiderman & Plaisant, 2010).

Questionnaires provide data about user perceptions. The Delphi Phase One questionnaire used yes/no questions (Appendix G). The panel focused on adaptability, practicality, usability, and ARCS motivation. The questionnaire elicited responses used to identify key areas in which consensus was needed (Clayton, 1997).

The questionnaires in phases two and three used a five point Likert scale design that helped identify the range of consensus (Appendices K and O). The Likert Scale is a popular format for gathering data and was found to be sensitive with small sample sizes (Sauro & Dumas, 2009). Richey and Klein (2007) recommended using questionnaires tested in previous research.

The format adopted for this study was validated in a recent internal validation study of a cognitive apprenticeship model for a computing education course design (Fernandez, 2014). Additionally, the questionnaire design was informed by analysis in the previous rounds (Hsu & Sandford, 2007). The Round Two Likert scale used a *strongly disagree, disagree, undecided, agree, strongly agree* format. In Round Three the format was changed to *not true, slightly true, moderately true, mostly true, very true* to offer greater discrimination between responses and increased rigor in the consensus process (Hsu & Sandford, 2007)

Data Collection and Analysis

Data collection began during model development and continued through the pilot studies and expert review of model components (Richey & Klein, 2007). A variety of narrative, categorical, and ordinal data were collected (Terrell, 2012). Data collection was terminated at the end of the third round of the Delphi expert review process.

Narrative data were collected during design and development in the form of researcher notes and a review of literature (Richey & Klein, 2007). The review of literature was updated at six month intervals during model development and enhancement. The data informed the analysis, design, development, and integration of the web-based combined laboratory model.

Narrative, categorical, and ordinal data were collected during the internal validation of the laboratory model. The pilot studies generated narrative data concerning the completeness, manageability, and sequencing of model components (Richey & Klein, 2007). The Delphi expert review process developed narrative, categorical and ordinal data.

Data collection in the Delphi review began with participant solicitation. The demographic survey generated categorical data regarding the computing education experience of panel members (Appendix C). Participants' demographic information provided detailed information and guided selection of a diverse panel of computing instructors with respect to education, computing disciplines, teaching background, and experience with laboratories.

Participants' responses and feedback provided narrative data during the Delphi process. Qualitative categorization techniques were used to organize data associated with adaptability, practicality, usability, and motivation (Cresswell, 2007). Descriptive analysis provided a detailed overview of the Delphi participant's feedback. The researcher analyzed comments to identify stakeholder concerns regarding model development, recommendations for enhancement, and areas where consensus was needed. Modifications were applied to the model during the Delphi process based on recommendations identified in the analysis.

The Delphi expert review, data collection and analysis process is summarized in figure 3.1. Data were collected concerning adaptability, practicality, usability, and motivation qualities of the web-based combined laboratory during three rounds of expert review. The data from each round were analyzed, the model updated, and consensus status determined.

The Round One questionnaire provided narrative and categorical data that guided analysis of consensus issues and model enhancements (Appendix G). The Round One data were also used to inform participants of the collective position regarding the adaptability, practicality, usability, and motivation design of the model. All panel feedback from the Round One questionnaire was provided to participants at the beginning of Round Two (Appendix J).

The Questionnaires used during the second and third rounds of the Delphi review provided ordinal data in addition to narrative data (Appendices K and O). Analysis of the narrative data informed determination of the collective position of the panel and enhancements to the model. Round Two panel feedback was provided to the panel at the beginning of Round Three (Appendix M). Ordinal data analysis yielded the measures of central tendency used to determine panel consensus (Appendix Q).

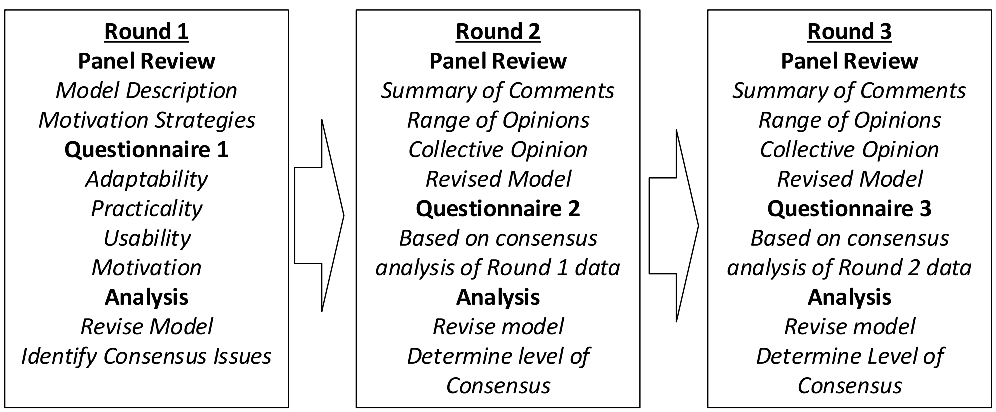

Figure 3.1. The Delphi review, data collection, and analysis process.

Data collected in the expert review process were analyzed and informed the study report. Qualitative narrative techniques provided a rich evolving description of the design and development process (Creswell, 2007). Results were interpreted in a narrative format guided by design and development research methods (Richey & Klein, 2007). A descriptive narrative with figures and tables created new knowledge about the adaptability, practicality, usability, and motivation qualities of a web-based laboratory model used in a computing education context. Additionally, the extensive narrative data supplied numerous enhancements to the model.

Model research is more generalized and conclusions tend to be associated with heuristics and broadly applicable principles rather than lessons learned. Data analysis was guided by the aim to contribute to the existing instructional design knowledge base and enhance the web-based combined laboratory model. Internal validation was used to enhance the model and advance the effectiveness of external validation.

Resources

The study required resources in the forms of people and technology. Human resources were needed to implement the Delphi expert panel. A group of 13 higher education computing instructors were recruited to establish a panel of experts who represented a diverse array of experience within computing education disciplines, teaching experience, and classroom formats. Technical resources included the use of email, an online survey host, and web-based data analysis tools. Email was used for communication between the participants and the researcher. The Survey Monkey (www.surveymonkey.com) online survey tool was used to create and host the demographic survey and three Delphi questionnaires. The measures of central tendency for consensus determination were generated in the Calculator Soup online calculator resource (www.calculatorsoup.com). U.S. Mail was used to ship the original signed informed consent documents between the researcher and the participants.

Summary

This study informed the design, internal validation, and enhancement of an ARCS supported web-based combined laboratory. Expert review methods informed model design and development and provided guidance for validation and recommendations for enhancement. While the laboratory was designed in the context of the needs of the non-traditional computing education student population, data from a diverse panel of computing education instructors broadened the perspective. The proposed Delphi panel included members with masters and terminal degrees, from diverse computing education disciplines, with experience teaching in different types of institutions in a variety of formats. A rich description of adaptability, practicality, usability, and motivation emerged. A validated model supports web-based laboratory designs that computing instructors can implement to sustain motivation and learning of computing students, including non-traditional learners, in a variety of disciplines.

Chapter Four

Results

Overview

The goals of the study were the design, internal validation, and enhancement of a web-based combined laboratory model for non-traditional computing education students. Data collection and analysis began with model design and development, and culminated with internal validation through pilot studies and a three round Delphi expert review process. The result was an enhanced laboratory model that can be adapted by instructors in a variety of higher education computing disciplines.

Chapter 4 presents the analysis results of a web-based laboratory model design and development study. The narrative description is presented in the general sequence of the development process. The findings emerged from an extensive review of the design, validation, and enhancement data.

Analysis

This analysis was based on design and development interpretation techniques outlined by Richey and Klein (2007). The intent was to derive meaning from the data analysis to expand the knowledge base and inform practice. ARCS motivation theory helped organize, summarize, and interpret by guiding the findings (Keller, 2010). The results were context specific. Meaning was created from the synthesis of related literature, actual design and development activities, the validation process, and a compilation of expert opinions.

Design and Development

Retrospective analysis of the design and development process increased understanding of the internal validation and enhancement processes (Richey & Klein, 2007). Profile and context data clarified the designer's motivation, the development setting, and the model's intended role. The web-based combined laboratory model was created in and for a real world academic context.

The creative process was initiated in an informal setting without financial assistance. Formal academic support was provided later with advice, scholarly studies, and feedback during doctoral studies. Over time a framework based on the Keller (2010) model of motivation began to take shape. The design resulted from the real-world experience of learners and their need for hands-on practice.

Inspiration for a web-based laboratory surfaced in a compressed undergraduate IT degree program for working adults. The model was envisioned as an innovative tool to provide learning resources to fill an experiential learning gap for non-traditional computing students. Although these students spend little time on campus they wanted opportunities to practice computing skills with real world hardware and software. A flexible design emerged that integrated a variety of existing learning resources in ways that supported the *attention, relevance, confidence, and satisfaction* necessitated by the ARCS model of motivation (Keller, 2010).

The initial design proposed gaining *attention* through the use of a variety of resources; aligning laboratory activities with course objectives to enhance *relevance*; giving learners control of the pace of learning to support *confidence*; and, providing opportunities to apply new learning to foster *satisfaction* (Green, 2012). Using the initial model a database design laboratory was developed for local classroom implementation incorporating Skillsoft © computer based learning (CBL) modules, YouTube© demonstrations, and hands-on experiential learning activities (Appendix B).

Pilot Studies

Three classroom pilot studies were undertaken over a 14 month period during the design and development process using the database design laboratory to validate internally the completeness, relevance, and flow of the components. Each of the three pilots was conducted in an active database concepts course in which the students were expected to create a simple relational database. The initial pilot validated the objectives and CBL components.

In an abbreviated implementation the first pilot did not include all laboratory components. Only the objectives and Skillsoft © CBL modules were included. The computer based learning modules were easily integrated into classroom lectures and discussions. The initial pilot study validated the relevance, completeness and flow of computer based learning activities.

The second pilot was conducted at the invitation of a colleague. One laboratory unit was presented each week for a period of four weeks in a database concepts course. The first hour of class was dedicated to laboratory activities. All components of the laboratory were included. The Skillsoft © CBL modules and YouTube © demonstrations were easily completed in the assigned one-hour time frame. Additional time was needed to complete a meaningful experiential learning activity. The completeness, flow, and relevance of all components were validated.

The third pilot was conducted during a database concepts course taught by the researcher. The students were assigned a design project in which they created a working database in incremental steps over a four week period. One laboratory unit was presented each week for four weeks. The laboratory units were sequenced to present one database design concept during the week before learners applied the concept in their database design project. As in the second pilot study, the CBL and simulation activities took under one hour. An additional 45 minutes was needed to complete the hands-on experiential activities each week. The completeness, flow, and relevance of the laboratory components again were validated. A six week three round Delphi expert review process extended the findings of the pilot studies in the internal validation process.

Delphi Expert Review

The Delphi expert review was conducted by a panel of experienced higher education computing instructors. The panel was chosen to review the model from diverse perspectives. Analysis of the panel demographics provided important insight into the panel's education and academic background. Figure 4.1 presents panel experience with respect to education, computing disciplines, and years teaching.

Highest Degree	**Computing Disciplines**	**Years Teaching**
Masters = 3	Networking = 4	Less than 4 years = 2
Doctorate = 10	Programming = 4	4 – 6 years = 1
	Database =1 (3)	Greater than 6 years = 10
	Web Design = (1)	
	Other = 4	
	(X) = secondary selections	

Table 4.1. The Number of Delphi Participants by Experience Category.

The majority of the panel earned terminal degrees. All had the minimum of a Masters degree. The networking, programming, and database disciplines were represented by the highest number of participants. Although four panelists listed database as a discipline, three of the four listed it as a secondary discipline. One panelist listed web design as a secondary discipline. The *other* category included the disciplines of engineering, management information systems, online education, and systems analysis, which were each selected by one participant.

Only two members noted less than four years of instructional experience. The perspective of less experienced instructors was considered important to validating laboratory usability. One instructor had between four and six years teaching computing classes. The majority of participants indicated over six years of instructional experience. Clearly panel composition displayed a diverse range of computing disciplines with high levels of teaching experience.

Panel selection focused on candidates with higher education teaching experience. Computing instructors from corporate or certification training programs were not solicited for this study. Table 4.2 displays the instructional environment of the Delphi panel participants. Just over half were teaching in non-traditional universities. The remaining members were evenly split between community colleges and traditional universities.

Type Institution	**Teaching Format**	**Experience with Labs**
Community College = 3	Local Classroom = 7	Traditional Campus Lab = 3
Traditional = 3	Online Classes = 3	Web-Based Lab = 7
Non-Traditional = 7	Blended Classes = 3	No Lab Experience = 3

Table 4.2. The Number of Delphi Participants by Instructional Environment Category.

Of the three primary teaching formats represented, the majority of panel members selected local classroom as their primary environment. Two participants noted experience with more than one format. Seven of 13 had some online teaching experience. Three participants reported no experience with laboratories. Again, this was important to ensure a novice perspective in the Delphi review process. Seven participants listed web-based laboratory experience, which provided an important perspective.

The Delphi panel was composed of members with experience across a range of disciplines from a variety of higher education institutional environments. The less experienced participants provided an important perspective with respect to the practicality and usability of the laboratory model. Overall, the diverse experiences of the panel members provided over 20 pages of rich descriptive and narrative data during the three rounds of the Delphi process.

Internal validation through the Delphi process extended the pilot study validation of completeness, relevance, and flow of laboratory components. The Delphi panel addressed issues associated with environmental factors, application in range of computing courses, and implementation by most instructors. The review was conducted in the context of model adaptability, practicality, usability, and ARCS motivation design.

Delphi Round One was initiated with a questionnaire composed of seven yes/no questions (Appendix G). An explanation field was provided for each question. Additionally, it included a field at the end to propose recommendations for improvement of the model. Research questions two, three, and four guided question design. Extensive participant feedback was received during Round One (Appendix J).

The Round One panel collective position was generally positive with 81% of responses falling in the yes category (Appendix Q). The areas of practicality (77%), usability (77%), Attention (69%), and Relevance (69%) were identified as possible areas where additional consensus was needed. Adaptability received a unanimous favorable rating. Confidence and satisfaction were close with 92% and 85% positive ratings respectively. Figure 4-1 displays the percentage of positive responses from the Round One Questionnaire.

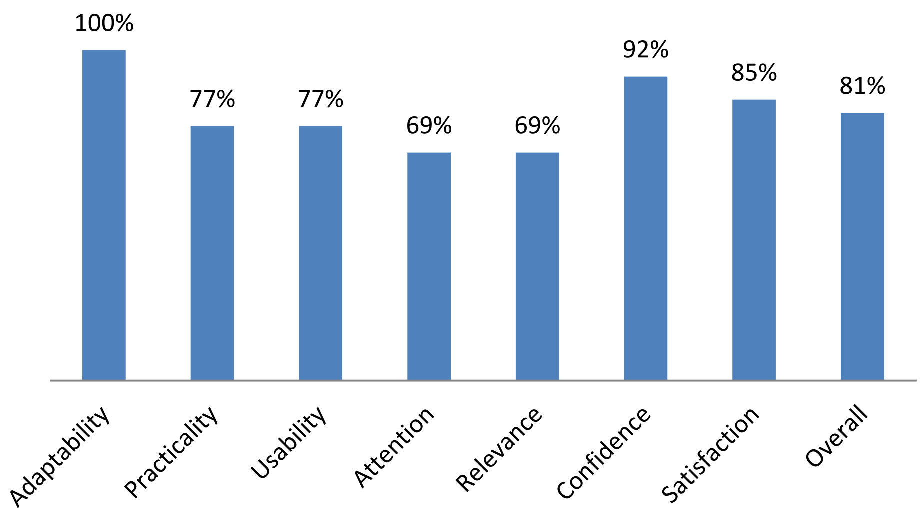

Figure 4-1. The Percentage of Positive Responses in Round One.

Panel comments were reviewed several times during the Delphi process and organized into four categories; *ARCS Design Recommendations*, *Instructor Reactions*, *Adaptability-Practicality-Usability Recommendations*, and *Issue Identification*.

ARCS Design Recommendations were consistent with theory and provided innovative ideas for implementing motivation with the model. Most of the feedback related to attention and relevance. Several ideas were put forward to gain and maintain attention. One instructor suggested using what-if scenarios:

What-if type scenarios need to be incorporated to gain and maintain learner attention.

Another cautioned not to use old learning materials:

If materials are dated or less relevant, student attention will fade.

In the context of attention a third instructor’s comments were a reminder of the power of hands-on activities:

The hands-on components will definitely retain their attention.

Another comment mirrored the value of hands-on learning in motivation design:

But, actually getting hands on experience with commercially available products would be better than hands on with something that the students might never see again.

An experienced instructor cautioned against using long instructional videos:

My experience is students do not watch video clips longer than 5-6 minutes. The sample videos were too long for example.

The panel offered several thoughtful comments regarding the implementation of relevant materials in the model. One instructor suggested utilizing activities that drive the application of industry best practices:

For the labs to be relevant, I would like to see more controls put in place that force a student to solve a solution on best practices, not a student's practices.

Another instructor observed that relevance in the delivery methods is not enough; the content must also be relevant:

Using the example in the document, if a student is designing an ERD, logical model, and physical model for an irrelevant database concept like employees, projects and departments I don't think the content has relevance even if the delivery mechanism does.

In addressing satisfaction the same instructor continued to stress the importance of content in achieving motivation design objective:

Again - the content here is what will provide the satisfaction. Busy work does not produce a satisfied student.

Integrating teamwork was suggested as a general recommendation in motivation design:

Overall, I would recommend involving teamwork.

The importance of the flow of components was reinforced with a reminder about the model phases:

The order of the model phases is important for example.

Instructor Reactions to the model mirrored the favorable questionnaire responses. One panelist expressed confidence in adapting the model to existing courses:

Assuming I was designing the content – I can answer yes this laboratory model would adapt quite well to courses I have taught and currently teach.

Another indicated the laboratory design corresponded with exercises in computing courses with which she/he was familiar:

The lab, as described, coincides almost exactly with most similar Lab exercises developed for basic database courses that I teach and have taught in the past, and it should work well.

The computer based learning and simulation components were appealing to one member:

While the laboratory component is standardized among instructors for my particular course, I would love to focus on CBL and simulation learning in an effort to minimize passive instruction.

Other responses were more critical suggesting the model was not adaptable to all computing education courses. One instructor noted the web-based model was not required across all disciplines:

You do not need remote laboratories (Computer Based Learning) in my programming courses. Students can perform many tasks on their computers.

In a similar thread another panelist suggested the laboratory would be better suited to teaching software application skills than programming:

It is more relevant for some areas (e.g., Excel Skills) than others (programming).

The challenge of integrating different learning resources into the combined laboratory model was expressed by a panelist who stated:

Integration of the wide variety of online tools is a challenge, not just in initial creation of a task oriented lab module, but in the ongoing maintenance. The online resources would need to be curated and the integration step would need to be simple "point and click" for the instructor and not need extensive testing.

Adaptability, Practicality, and Usability Recommendations indicated a range of ideas that could be considered best practices. For example, one suggestion reminded the researcher of the importance of simplicity:

This stuff should NOT be rocket science to create or use.

Two participants proposed ideas for simplifying instructor managed laboratory resources. One instructor suggested:

Develop the model so interested teachers on an Open Source basis could curate a web-based hands-on experience for students.

The other instructor proposed a curriculum based approach:

A working curriculum model should be demonstrated to provide a basis for

> *instructors to improve upon and utilize in their work.*

Another suggested integrating resources from user groups:

> *When possible, integration with materials that are from or related to the target tool or program, or somehow connected to the vendor (perhaps from a user group) would increase student buy-in to the program.*

Issue Identification is among the most important tasks of a Delphi panel. This panel quickly recognized a critical limitation of the model. The significant skill and time required to create laboratory resources impacted negatively the practicality and usability of the model. A panel member clearly articulated the need for modular components:

> *So to create a body of instructors who are willing to innovate with the notion of a web-based combined lab there would need to be components already tested that could be linked together like Legos. So it is a matter of skills AND time.*

Another instructor shared the need for additional training in developing and using computer based learning and simulation materials:

> *I feel that I would need more professional development on the CBL and simulations activities.*

Two instructors advocated for reusable materials to reduce the time and effort needed for instructors to create resources. One stated:

> *Effort versus practicality is a real consideration. If time is invested to design can it be reused, or repurposed for the future.*

In the context of usability the other expressed doubt:

> *I believe so – but it would be a challenge to create all the materials rather than using or adapting existing material.*

A well known benefit of expert review is the identification of important limitations or issues (Linstone & Turoff, 1975). The panel quickly recognized the lack of content for many computing courses was an important limitation of the laboratory model. Laboratory content was a significant theme in the Round One discussion. The panel noted that content was an important influence in ARCS motivation design. Content availability affected panel perceptions of the model. Several ideas for developing and managing computing content in an open-source web-based environment were proposed in Round One and the discussion continued in Round Two.

Delphi Round Two commenced with a questionnaire using a five point Likert scale with seven questions (Appendix K). Comment fields were included for the questions. A separate comment field was provided to make recommendations for improvement. Research questions two, three, and four guided survey design. The survey was edited slightly to streamline the questions.

The Round Two questionnaire was completed by all 13 panel members. Consensus in round two exceed the measures Hsu and Sandford (2007) recommended; 100% of selections fell within two points, were rated greater than 3, and the median was higher than 3.25 (Appendix Q). The highest consensus was in the areas of *confidence* (mean=4.39), *relevance* (mean=4.31), and *satisfaction* (mean=4.31). The model's *adaptability* (mean=4.23) *and practicality* (mean=4.23) were also rated high by the panel. The lowest level of consensus among the panel related to *usability* (mean=4.08) and *attention* (mean=4.00). Figure 4.2 displays the mean scores for the Round Two Questionnaire.

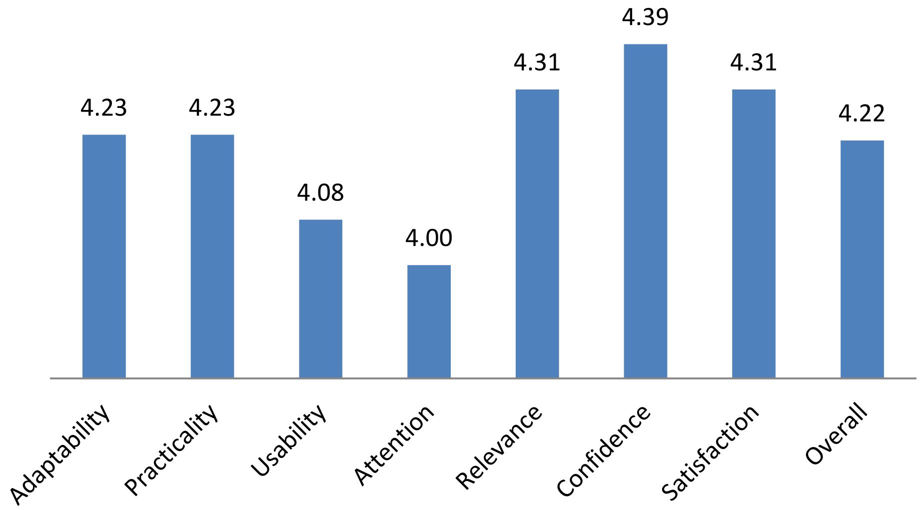

Fig. 4-2. The Mean Response Scores for Round Two.

Comments were reviewed and analyzed during the Delphi process. After review the comments were organized into the same four categories as the Round One comments; *ARCS Design Recommendations*, *Instructor Reactions*, *Adaptability-Practicality-Usability Recommendations*, and *Issue Identification*.

ARCS Design Recommendations exposed a difference of opinions about the value of ARCS motivation strategies. One instructor questioned the cost of implementing ARCS motivation into laboratory content:

> *I am not sure how practical the ARCS learning model might be. From my perspective, the assumption is that all learners will come to this model with at least similar learning levels. Additionally, just because the ARCS might be a good model does not mean that it will outweigh costs of learning: especially, when up against traditional and more economical models.*

Another instructor clearly supported using ARCS motivation strategies in the laboratory:

The ARCS model is a learning model which from my perspective is adaptable to learning models on "any" topic.

While some comments provided explicit recommendations to guide ARCS content design others shared conditional insight. For example an instructor noted that attention was dependent on specific content and cautioned that insignificant activities will not hold learner attention:

(Attention) depends on the choice of actual lab exercises. If trivial, students will quickly lose interest.

One instructor suggested that simulation lacked realism and relevance was contingent on using real-world laboratory equipment:

Depends on the relevancy of the laboratory model to the course material, and how close the assignment is to the real software, hardware, or methodology being presented to the student over the course of the class. Simulations are OK, but the real benefit will be realized when the student experiences the same user interface.

Another mentioned the value of simulation in an unconditional context:

Simulation or virtualization provides the opportunity to turn theoretical knowledge into practical knowledge. Retention and understanding of subject matter increase as students are able to apply what is learned. Different touch points help to reinforce knowledge.

Concern over the time allotted to laboratory activities was expressed by another instructor who recommended more time for complex topics:

Also, some of these assignments could take more than 5 weeks. Suggest tying courses together where a larger assignment could span 4-5 weeks with deliverables.

A reminder that long videos may not hold attention, while reinforcing the importance of bringing theory together with hands-on exercises, a panelist suggested reinforcing theoretical knowledge and hands-on experience with reflection:

For example, incorporating Linda tutorials into my online courses has not been successful. I think a good laboratory model should incorporate hands-on experience and theory somehow together. I prefer a model which meshes theoretical knowledge with hand-on experience reinforced with reflection.

Two additional comments provided reminders for ARCS motivation design. One instructor pointed out that confidence comes with practice:

If the lab is strongly integrated with subject matter and students use the tools provided confidence will increase with "practice."

The other reinforced the importance of scaffolding feedback to novice computing students:

(If) the model includes some type of scaffolding built-in students with limited technical skills can benefit from it.

Instructor Reactions provided a range of opinions and often had a conditional tone. For example several instructors had a positive view of the model given adequate content:

It would be practical if a good amount of relevant content was available for the different learning objectives in the courses I teach. If content were not available *then practicality would be more limited as I would have to create the content at some instructional design expense in terms of financial and time resources.*

Another instructor had a similar positive but conditional reaction:

I teach on ground: programming (C/C++, Java), software engineering, systems analysis and design, and database. I think this model could be adapted to meet the needs of these courses assuming that content could be created or is available.

A third instructor indicated that plenty of content was available:

There is a wealth of content and information that can be provided to students to enhance the learning experience as they progress through a lab assignment.

Real world application was another condition mentioned with a caution:

If the tie into real world applications (uses and tools) is achieved, then this model could be very useful. If not, students will not take the time to look at the material and in some cases may skip the assignment and take the hit on points.

Some concern emerged with respect to the general applicability of the laboratory model:

The lab model should not be generalized as applicable to all computing education. There are certain courses where it is very applicable. For example, Web programming. In other cases, beginners can use this approach, but not for advanced level learners.

In the context of adaptability an instructor expressed doubt regarding the general applicability of the laboratory to all students:

If by computing students you mean IT driven students, I am inclined to agree. However, non IT driven students, I am inclined to disagree.

Another instructor had a similar opinion with respect to applicability of the laboratory model across all computing courses:

The terms "computing content" and "computing students" are too general. The model will work for some course types, but not to others.

Adaptability-Practicality-Usability Recommendations provided practical ideas to improve the model. For example one instructor suggested virtual machine (VM) technology for integrating hands-on exercises:

The use of virtual machines is a superior way of learning for hands-on labs. Unlike simulations, virtual machines allow for a full range of commands.

Another recommendation proposed the use of smart phone tools such as calculators to assist students in completing labs:

Students have smartphones to access online calculators or dashboards. This is simpler than using PC-based html tools that may be too complicated for students.

One panelist advocated for instructor led laboratories:

I believe the trick will be to allow the instructor's method of teaching to be fully integrated into a model that mixes technology and a strong instructor learning led teaching environment.

In the spirit of an instructor led laboratory another suggested the instructor demonstrate the desired skill:

I would recommend that the faculty go through an example or encourage the students to do a "create a DB" walk-through so they understand the basics of how each tool works.

Creating an open-source industry movement to guide content development was suggested as a way to create an incentive for addressing the challenges of implementing a web-based laboratory:

> *No incentive from the university to create such a tool. If there was an Open Source industry movement that would provide UI standards to simplify development and reward investments in such development.*

The important issue of plagiarism in web-based programming exercises was addressed by a panelist:

> *Attempts have been made to translate integrated development environments online, but many of these have features that may present a challenge in tracking authenticity of an individual's own work.*

An instructor suggested the use of wizards to simplify laboratory implementation:

> *To minimize the time needed to implement a web-based laboratory think about using wizards in a cloud environment which would provide a common platform that is similar for all courses.*

The concerns around content availability and instructor course design skills continued to influence perceptions of model practicality and usability. A new concern emerged regarding student skills with laboratory tools such as Visio. The panelist noted that students must know how to use the software needed to complete laboratory assignments:

To build a successful flowchart and database, students must understand how the tool works.

Issue Identification suggested the concerns expressed with regard to laboratory content in Round One persisted in Round Two. No new issues were identified. Many comments expressed conditional approval of the laboratory model contingent on the availability of appropriate content.

In one particularly detailed comment the panelist described her/his significant concerns with respect to content and implementing the model:

> *Whether or not it could be used as a framework for novice and experienced designers depends completely on the content which will vary from course to course. As an example, creating good artifacts to simulate assembly of a personal computer vs learning artifacts to simulate how pointers to structures are used in vectors of structures goes from the concrete to the abstract. Simulation for the abstract is more difficult and will require more experience. I understand that there is a difference in the model and the implementation of the model. I don't have any problems with the model - I do however think that implementing the model will be more difficult - if not impossible - with some course requirements that I teach without significant investment in design resources.*

Another comment provided a clear overview of the issue in terms of the adaptability and practicality of the laboratory model:

> *In terms of adaptability, I believe the model is adaptable to almost any pedagogical goal - but the real question is the practicality of doing so. IF there is not material already available and accessible, then it will have to be designed. Design costs money, resources, time and may differ based on learner population. It may not be practical to do the design work to create the learning artifacts for a low enrollment course.*

By the measures of median and mode the panel reached consensus in Round Two (Appendix Q). The Delphi could be terminated after consensus in Round Two. A third Delphi round increased the opportunity for the panel to make inputs toward enhancement of the model and improved the reliability by adding a successive iteration of consensus. Two rounds of successive consensus are considered more reliable than one (Hsu & Sandford, 2007).

While the availability of content continued as a theme in Round Two it was not as dominant. New concerns about the adaptability of the laboratory to different courses and student populations emerged. Confidence in the laboratory design increased and was often expressed in a conditional context. For example, given appropriate content the laboratory model would benefit only certain disciplines and student populations. The conditional view of the laboratory continued into Round Three.

Delphi Round Three was the final questionnaire, which like Round Two used a five point Likert scale with seven questions (Appendix O). The Round Three questions were edited slightly and the Likert scale format revised to allow greater discrimination in the responses. As in the previous questionnaires a comment field was included for each question with a separate comment field for improvement recommendations. Research questions two, three, and four guided the survey design.

The Round Three questionnaire was completed by 12 of the 13 original panel members. Consensus in Round Three exceeded the Round Two measures (Appendix Q). 100% of selections ranked between four and five on the Likert scale and the median score was higher than 3.25. The relative consensus between the topics of the questionnaire was stable in comparing Round Two and Round Three Results. Although consensus increased for all topics in Round Three, the consensus levels for *adaptability* (mean=4.58), *relevance* (mean=4.83), *confidence* (mean=4.64), and *satisfaction* (mean=4.58) remained relatively higher than *practicality* (mean=4.45) and *usability* (mean=4.36). The over half point increase in the mean for *attention* (mean=4.58) was noteworthy. Figure 4.3 displays the mean scores for the Round Three Questionnaire.

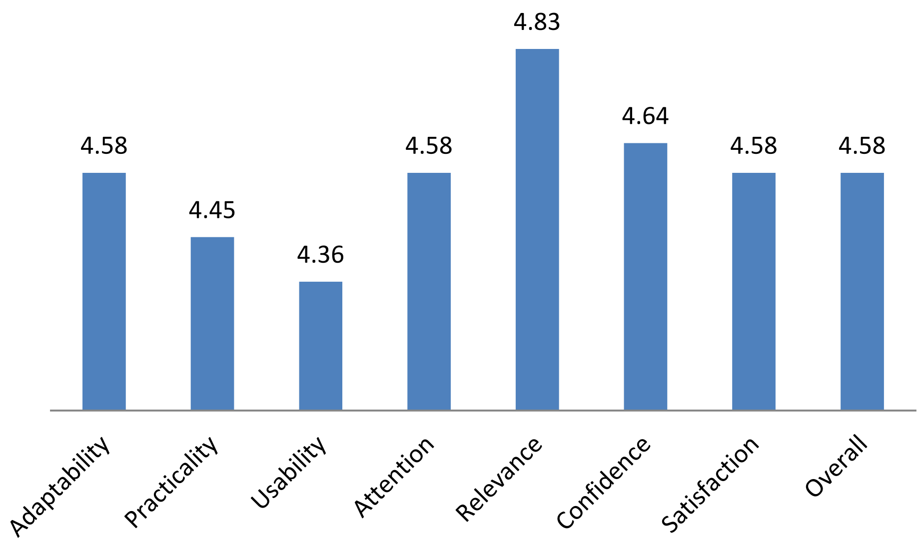

Fig. 4-3. The Mean Response Scores for Round Three.

Instructor comments reflected less focus on contingent requirements about available content. While some doubt was expressed opinions were mostly positive. Several innovative ideas were proposed to enhance the laboratory implementation and to develop open environments for creating and sharing computing content. Often comments provided rich detail with multiple ideas; in some cases comments were broken out and shared in this analysis as more than one recommendation. The Round Three comments were reviewed and analyzed during and after the Delphi process. After review the comments were organized into the same four categories as the Round One and Two comments; *ARCS Design Recommendations*, *Instructor Reactions*, *Adaptability-Practicality-Usability Recommendations*, and *Issue Identification*.

ARCS Recommendations related to best practices and a continued desire for more clarity regarding the implementation of the ARCS motivation framework in the model. For example, one panelist was unclear about the function of attention in the model:

> *How prevalent must the attention component be part of a concept (i.e lesson, module, unit, etc.)? The sense I have this is used to begin a lesson, but it may have to continue throughout the concept. Perhaps, more information around "attention" is necessary.*

A second comment illustrated concern regarding the relevance of laboratory implementations to different audiences:

The one area for revision is the actual definition of "relevance" With the edits on page 4, relevance should also describe group needs in addition to individual needs. Given the variety in learning formats, it is important to describe this model in terms of the audience.

The panelists also shared several best practices for ARCS integration. One comment related course outcome mapping to improved clarity in the ARCS motivation design:

By mapping outcomes to course objectives, students and faculty will have a mutual understanding on how the course will progress. The ARCS framework now has additional clarity on the practicality. I believe that in additional mapping course objectives, the ARCS framework needs to mapped to a curriculum.

One instructor wondered if group laboratory exercises would increase student engagement:

Maybe if the design was included somehow as an in-class (versus an individual lab) participation project. I think students might engage more.

Another instructor advocated for the benefits of instant automatic feedback:

In an ideal situation (difficult to achieve in practice) automatic, instant feedback from the simulation would help students gain confidence in their work.

A reminder about the relationship between competence and confidence was shared by a panelist:

Small wins build competence and then confidence.

One panelist wanted to see examples of best practices and noted that sharing best practices will improve the student learning experience:

Would like to know 1-2 faculty success stories where lab has worked and students have bought in. Sharing best practices of what works in lab model will improve students' satisfaction.

Instructor Reactions were for the most part positive. There were a few negative reactions and some positive opinions that were contingent on certain conditions such as the type of course or student.

For example, one instructor suggested the laboratory model was more work than students were willing to take on:

I am beginning to think that this LM might be more work that most students can find time for and/or have the capability to follow from A to Z and then apply it to coursework objectives.

In the same theme another instructor suggested students’ attention spans may not fit the laboratory model while at the same time noting it was great for faculty:

I am not too sure that our students will have enough of an attention span to engage in this LM the way it is designed. However, from a faculty perspective, the concept is great.

Numerous comments reflected a conditional positive opinion with respect to certain computing courses:

If an IS&T course is Networking or Enterprise Security hands on experience would significantly help students relate to real world. The web-based lab could minimize the hurdles of gaining access to real equipment and learning the idiosyncrasies of the equipment.

Similarly, another comment reiterated the theme that laboratory content was a conditional factor:

Lab information is generally available, but depends on which course. Some tools/labs are provided by the school and licensed on a per-course basis. Would be very true if you can guarantee access to the resources.

One instructor suggested the laboratory would be usable:

If a lab collaboration Wiki existed

Another advised a realistic UI is an important condition for relevance:

Yes (the laboratory can be used to present content in a relevant context) if the UI presents realistic circuits or networks or technical problems and if the "lab instrument dash boards" look like control panels of realistic devices.

A few comments reflected a mixed opinion of the laboratory, for example:

> *I've used components of the lab model with mixed results in my classes. I find the resources easy to find/use, but need more guidance in the best practices to implement in the classroom successfully.*

In another comment the instructor was optimistic about the availability of online content but concerned about the academic honesty risks of such content:

> *From an academic honesty perspective, online resources present a wealth of supporting knowledge, but an opportunity for students to take advantage of systems.*

Although ease of use was a conditional concern of one panelist, the comment expressed an overall positive opinion of the laboratory model similar to most reactions in Round Three:

> *Depends on how easily students feel they can access and work through the lab. But again, I think this LM concept is great.*

Most of the Round Three instructor reactions were short positive reflections that addressed a single issue such as:

> *I like the concept of smaller models that are focused and narrow. The path to completion is shorter so the reward of learning is easier to attain.*

Comments also indicated an affirmation of the immediate value of the model. One instructor saw the opportunity to use the lab with an existing course:

> *From my perspective, I see the opportunity to formalize my existing course with this portion of the framework. My course contains components for additional learning and motivation to further learning by solving more challenging problems.*

Another panelist commented about a hopeful future for the laboratory model:

> *This model will allow instructors to teach current and relevant skills without*

continually updating materials. Once there is cohort of instructors collaborating on the class, enhancements and continuous improvement will be the norm.

One final instructor reaction is shared because the panelist expressed a unique perspective of the laboratory model:

I think of this as a "Dim Sum" lab, as opposed to a "Full Meal" lab. It is a small learning module that does not require much setup or study to create for the instructor and does not require much effort to setup and play with for students.

Adaptability-Practicality-Usability Recommendations accounted for the largest segment of comments in Round Three. Many of these comments were quite dense and addressed multiple topics. Several very innovative ideas were proposed, such as a suggestion for a split screen user interface using a pc and a smart phone:

Would need to have split screen user interface to present on one screen high level concepts in flow chart or circuit diagram form and concurrently a low level screen to present progressive dashboards of instruments needing configuration. This would be similar to the user interface of various html WYSIWYG editors. Or synchronize screens between a PC for the big picture flowchart/circuit view and a smart phone for the dashboard view.

A simple credentialing system was another novel suggestion:

The thought that came to mind when reviewing the latest revision is that newer credentialing systems, such as badges, could be combined to provide students with micro-credentials that highlight learned concepts.

The Wiki idea mentioned earlier was extended with descriptive detail:

Rather than create modules myself it would be most practical to participate in a Wiki so I could take existing modules and customize or enhance them and then contribute my value-added modules to the Wiki for others to use.

Virtual reality was proposed as a way to demonstrate laboratory skills:

It would be helpful for instructors and students to have virtual reality or augmented reality videos on Youtube that show someone doing the lab.

Some innovative ideas were proposed for sharing and organizing content, such as a peer-evaluated website:

A curriculum sharing site, that can be mapped to standards (i.e. ACM, IEEE, etc), combining this proposed framework (and other frameworks) may provide a catalyst on the importance of computer education. As an instructor, being able to share resources and find lesson plans that are relevant to course objectives is a time consuming process. Have a resource that could be peer-evaluated and approved may help reduce the challenges with developing curriculum and learning tasks associated with a course.

Another idea for organizing content involved creating a database of standard computing device inputs/outputs and diagnostic tools:

Define a database architecture for inputs/outputs of "industry standard" computing and networking devices (switches, routers, gateways, firewalls, etc...) and software diagnostic commands/tools (PING, TRACERT, etc...). Then various labs could be created by instructors developing Excel Macros that calculate the values of the input settings of devices and produce the appropriate output states.

Listed below are several concise best practices proposed by the panel to improve implementation of the laboratory model:

A step-by-step approach needs to be incorporated in teaching very advanced concepts.

Aim to have several simple lab experiences per week.

Some progressively difficult labs would be useful.

Focus on short lesson format where the goals are just a small stretch.

Additional comments provided practical enhancements:

All error output during operations should be trapped and provided to the user.

Provide examples for faculty to follow, methodology, for using tools in classroom.

Make a Youtube video that explains the goal of the lab and… implementation steps.

Video tutorials, especially for programming, could benefit from a central source.

Expanding on the earlier video tutorial idea the panelist added additional detail about the value of such resources:

> *In computer programming, there are a number of free online tutorials available (i.e pvtuts.com). However, a curriculum site dedicated to computer science could be a catalyst. This would differ from a Khan Academy where the concepts for programming are taught from the ground up, rather than using visual tools that may place the emphasis on a tool, rather than a concept.*

One final best practice was proposed to enhance model implementation related to platform-independent resources:

> *Platform-independent resources are paramount. Many examples are specific to the language or operating platform. An opportunity to emphasize that concepts do have computing limitations would be relevant in any tutorial.*

Issue Identification in Round Three was minimal. No new issues were identified and only one comment touched on the concern expressed in an earlier round with the use of video presentations in the model:

Have received feedback that students do not like going through exercises in class or watching the videos.

In the spirit of the consensus two comments summed up the Round Three feedback. One instructor mentioned the flexibility of the ARCS framework in the context of the database design laboratory:

This demonstrates that the ARCS framework has a natural flexibility that can incorporated with the laboratory model.

The other panelist expressed confidence in the outcome of laboratory designs using a web-based combined model:

The model is very doable and can to lead to overall student success.

In addition to reaching a second consensus in Round Three the Delphi panel discussion shifted to more confident and positive feedback. No new issues were identified and the volume of recommendations was much larger than earlier rounds. Many of the recommendations included rich detail, which added depth to model enhancement.

The first Delphi round ended with a low level consensus and significant concern about the availability of content. The discussion in Round Two shifted to a conditional positive view of the laboratory model. By Round Three the discussion shifted to an optimistic advisory tone and the consensus increased for a second successive round. The

Round Three consensus was well above recommended levels for Delphi expert review (Appendix Q).

Findings

Numerous findings emerged throughout the course of the web-based laboratory development project. Discovery was a natural part of each step of the process and was used to inform future steps. The literature review informed initial analysis, development, and design. Subsequent enhancements were informed by pilot studies and a Delphi expert review.

Literature Review

The literature review yielded several important findings about laboratory use in computing education that guided model analysis and development. Laboratories provide environments that allow students to gain skills through hands-on experience with real world computing hardware and software. Several laboratory formats are used in undergraduate computing education programs.

Local campus facilities are commonly used to host laboratory classes. While campus facilities afford hands-on experience with real equipment high maintenance costs, restricted access, and limited flexibility diminish laboratory effectiveness. Web-based laboratory formats have emerged as low cost options, which allow open access and learner control.

Web-based simulation laboratories are accessed through the Internet and use software to replicate laboratory experiments. Simulation software is inexpensive, models real laboratory equipment, and facilitates multiple observations of the experimental process. Reduced fidelity is a constraint of simulation software.

Web-based remote laboratories allow learners to experiment in an authentic computing environment using real computer hardware and software with significantly lower operating expenses than hands-on laboratories. Students manipulate experimental equipment remotely and laboratories can be shared among multiple learners without temporal or physical restrictions. Remote laboratories have been criticized for a lack of physical presence and functionality that is too complex for novice learners.

Web-based combined laboratories integrate multiple laboratory formats and learning resources. An advantage of combined laboratories is flexible access to a range of materials that allow students to review and rehearse experimental concepts prior to completing a laboratory assignment. CBL and simulation components incorporated into combined laboratory formats help novice learners prepare for complex hands-on laboratories.

Model Design and Development

The laboratory model was developed in an active process by an experienced computing instructor during the course of teaching non-traditional students. Higher education instructors are in a unique position to identify deficits in academic programs and are capable of developing solutions. Relatively few resources were needed to create, implement, and internally validate the laboratory model.

The ARCS model of motivation was a necessary factor in the model design. Each model component was developed to incorporate some or all of the ARCS motivation elements. Although not an all inclusive list, examples included: objectives aligned with learner goals for relevance; CBL modules allowed learner control to maintain attention; simulations built confidence; hands-on skill building boosted satisfaction; and, learning resources selected to sustain attention, relevance, confidence, and satisfaction.

Model development was informed and enhanced by internal validation of the model. Three pilot studies guided improvements to component sequencing and flow. Expert review provided rich feedback and recommendations that advanced model adaptability, practicality, usability, and ARCS motivation design.

Pilot Studies

Each of the three pilot implementations extended the findings of the previous study. The pilots were all conducted by the researcher in database concepts courses presented in a local campus classroom learning environment. Consistency of the pilot implementations helped relate the findings from one pilot study to the next.

The first pilot was implemented in a database concepts course and demonstrated completeness of the objectives and computer based learning modules. Only the CBL module was implemented. It fit easily into the four hour class period and was related well with other activities.

While the first pilot was conducted by the researcher while also teaching the class, the second pilot was conducted by the researcher in a colleague’s class. The simulation and hands-on exercise were included in the second implementation. The sequence of CBL, simulation, and hands-on exercise components were appropriate and the material supported the other classroom activities. The hour of class time set aside for the laboratory was inadequate; the CBL and simulation required 40-50 minutes and the hands-on exercise required an additional 45 minutes. The first two hands-on exercises were conducted as individual activities and the final two as small group activities. Both formats fit well in the local classroom learning environment.

The final pilot began just before the end of Delphi review and benefitted from the expert review feedback. All laboratory components were included. Based on feedback from the Delphi panel the hands-on exercises were conducted in small groups of three students. Due to the timing limitations identified in the previous pilot additonal time was allotted to the laboratory. An hour and half proved to be adequate for the CBL, simulation, and hands-on exercises. Additionally, a program requirement necessitated reversal of the third and fourth modules. The change was accommodated seamlessly, which demonstrated the flexibility of the model.

Delphi Expert Review

A three round Delphi panel review of the model took place over a six week period. The panel members were 13 experienced higher education computing instructors from a variety of academic backgrounds. The panel gave honest reactions, provided rich feedback, and shared helpful recommendation for enhancing the model in the context of adaptability, practicality, usability, and ARCS motivation design.

The panel opinions in the first round were most positive about model adaptability and ARCS motivation with respect to confidence and satisfaction. The opinions were less favorable regarding practicality and usability. The ability of the model design to support attention and relevance garnered the lowest instructor confidence. The panel identified a perceived lack of laboratory content as an issue that influenced the practicality and usability of the model.

The collective position of the panel after round one indicated additional consensus was needed with respect to attention and relevance. The confusion expressed in panel comments about the different roles of the laboratory components informed clarification to the laboratory overview used in Round Two (Appendix I). The web-based laboratory formats and CBL descriptions were expanded. Several best practices were added to the motivation strategies and the purpose of the pilot laboratory was explained in greater detail.

While an acceptable level of consensus was achieved in Round Two individual mean scores indicated consensus around usability and attention continued to be relatively low (Appendix Q). The median score for all topics was four. Panel opinions were generally positive with conditional approval contingent on available content. Accessibility to content continued as an issue to a lesser degree.

The panel provided recommendations with increased detail in Round Two (Appendix M). The proposals tended to focus either on web-based content management or best practices to improve ARCS motivation strategies. Some confusion was evident in comments regarding the use of objectives.

Instructor comments and recommendations guided the second enhancement of the laboratory overview (Appendix N). Further clarifications were made to descriptions of the pilot implementation, objectives, CBL, laboratory activity, and motivation strategies. Additional room for consensus existed. A third round offered additional feedback, enhancements, and panel consensus. The third round was the final model review.

Panel reactions in Round Three were clearly positive and reflected a confident advisory tone (Appendix P). Fewer opinions were shared while recommendations for enhancement increased. Several comments offered rich multi-layered advice. Consensus increased across the board. While mean scores varied the median scores increased from 4 to 5 overall (Appendix Q). The mean score for usability remained at relatively low but acceptable level. The mean score for attention increased and was equivalent to the overall mean score for Round Three.

Summary of Results

The result of this study was an internally validated, enhanced web-based combined laboratory model. The design and development process continued from initiation of the project through the enhancement steps undertaken during pilot studies and the expert review process. The model grew out of a need for hands-on experiential learning by non-traditional adult students in a compressed undergraduate information technology degree program.

Six important findings contributed to the result of the study:

1. An experienced computing instructor can identify a learning challenge and develop a model to address the challenge with relatively few resources.
2. A procedural development process undertaken in a real-world working environment supported the design, internal validation, and enhancement of the laboratory model.
3. Multiple pilot studies validated the flow, completeness, and relevance of laboratory components in a local campus classroom environment.
4. An expert panel of higher education computing instructors reached a consensus approval of the ARCS enabled web-based combined laboratory model during two successive rounds of a Delphi review.
5. Experienced instructors provided numerous relevant enhancements to the adaptability, practicality, usability, and ARCS motivation design of the web-based combined laboratory model.

6. The reaction of computing education instructors to the adaptability, practicality, and usability of the ARCS-supported web-based combined laboratory was positive.

Chapter Five

Conclusions

Overview

This chapter extends the description and analysis of study results presented in the previous chapter. A web-based laboratory instructional design model was developed to support computing students' hands-on experiential learning. The model was validated internally and enhanced during pilot studies and a Delphi expert panel review. Conclusions are interpreted in the context of the research questions. The strengths, weaknesses, and limitations of model development and validation are examined. The implications of the model in undergraduate computing education are explored and recommendations for future research presented. Best practices are offered to inform laboratory design, implementation, and research.

Conclusions

The benefits of hands-on experiential learning in a laboratory environment are widely understood in engineering, science, and computing disciplines (Abdulwahed & Nagy, 2011; Corter et al., 2011; Konak et al., 2014). Laboratories allow student discovery and practical experience with real-world equipment. Laboratory experiences increase learner understanding of course concepts, domain skills, and problem solving strategies (Chen, 2010).

Web-based laboratories have been explored as a way to reduce costs and expand learner access to laboratory facilities. Students enter web-based laboratory environments through the Internet and are remote from the experimental equipment. Simulation and remote laboratories are the primary implementations for web-based laboratory classes (Corter et al., 2011).

Hands-on, simulation, and remote laboratories have difficulty providing a full range of experiential learning opportunities (Abdulwahed & Nagy, 2011). Combined laboratory formats have been used to create laboratory environments that more fully align with learners' experiential learning needs (Cano, 2010; Corter et al., 2011; Green, 2012). A web-based combined laboratory model was developed merging computer-based learning with simulation, and remote laboratories. The Keller (2010) ARCS motivation model was used to incorporate attention, relevance, confidence, and satisfaction into the laboratory components.

Three pilot studies and an expert review by experienced computing instructors examined the internal validity of the model with respect to adaptability, practicality, usability, and ARCS motivation design. Expert perceptions, feedback, and recommendations guided revisions and enhancements to the model design. Panel consensus over three rounds of the Delphi review process indicated internal validation of model components.

Research Questions

How are web-based laboratories currently utilized in computing education courses? Laboratory exercises increase learner experience in the practice of experimentation while providing an opportunity to work in real computing environments. Access to expensive real-world computing equipment prepares students for work in a corporate computing technology setting (Wolf, 2010). Relevant laboratory exercises prepare students for new jobs (Choi et al., 2010). Experiential learning from laboratory activities provides an opportunity to develop the expertise demanded by industry. Computing education students use laboratories to gain hands-on skills, solve real-world problems, and gain a better understanding of technology concepts (Chao, 2010).

Laboratory experiences are a way to increase student understanding and application of learning materials (Corter et al., 2010). The conceptual framework of a technical discipline is reinforced by laboratories (Lahoud & Krichen, 2010). Wolf (2010) noted that exposure to potential problems and failures are an important feature of a laboratory education. Laboratories help educators meet the challenges of preparing computing education students to handle complex technical problems (Uludag et al., 2012).

A review of laboratory studies illustrated benefits from the use of laboratories in undergraduate studies. Students who had both simulation and remote preparation had significantly higher achievement in an engineering course (Abdulwahed & Nagy, 2011). Hands-on laboratories supported with a laboratory manual are most suitable for students with a read-write learning style, whereas combined simulation and remote laboratories used with the laboratory manual adapted the hands-on laboratory to the needs of students with visual and kinesthetic learning styles.

Corter et al. (2011) concluded that students can learn effectively in hands-on, simulation, and remote environments and noted no significant difference in the conceptual knowledge tests between students using the three laboratories. Wolf (2009) concluded that definite learning occurred in both lecture and laboratory assessments at nearly the same level. He noted that lectures and laboratories are equally important. The most learning occurred with novice learners who had one or fewer prior networking courses.

Comparing the inquiry-based design with a laboratory using prescriptive step-by-step instructions, Konak et al. (2014) concluded that students who completed laboratory experiments with the Kolb’s Experiential Learning Cycle (ELC) design had higher levels of competency development and interest. Sarkar and Petrova (2013) noted that once foundational knowledge is gained more sophisticated laboratory tools can be used. They concluded the use of a simulation laboratory increased student knowledge and comprehension in an introductory networking class. Cano (2010) concluded that the simulation laboratory helped students develop a deeper understanding of the topic and perform better on the assessment. Lahoud and Krichen (2010) noted that although students prefer hands-on laboratories a dual learning path was evident. Students with more experience benefitted most from hands-on and remote laboratories, while simulation and hands-on laboratories were more effective for novice learners. They concluded students are more engaged in computing classes complemented with simulation laboratories to assist in learning course objectives.

How must an ARCS - supported web-based combined laboratory model be revised to promote the motivation and learning of non-traditional computing education students? Motivation and learning revisions to the ARCS – supported laboratory design were informed by an Instructional Design and Development (IDD) process that included model development, pilot studies, and a Delphi expert panel review. The development process used the ARCS motivation theoretical framework to inform model revisions (Keller, 2010). Pilot studies of a database design laboratory validated internally the flow, relevance, and completeness of model components. The conclusion drawn from model development and pilot studies was the need for an expert panel review to extend the revisions (Richey, 2005).

A panel of experienced computing instructors evaluated the model with respect to attention, relevance, confidence, and satisfaction (ARCS) during three rounds of a Delphi expert review process (Keller, 2010). A questionnaire solicited perceptions, feedback, and recommendations in each round. Revisions were made to the model based on panel feedback at the end of the round.

Round One panel consensus regarding ARCS motivation strategy was high for the ability of the model to support confidence and satisfaction. The lowest levels of consensus in Round One were expressed for attention and relevance. The low ratings were related to concerns about the availability of laboratory content and confusion about different laboratory formats. While the panel offered specific recommendations for improving motivation, the feedback regarding attention and relevance indicated misunderstandings about the laboratory design. Differences between web-based simulation, remote, and combined laboratories were unclear. The laboratory descriptions were clarified in the panel review materials prior to Round Two to address the areas of confusion.

The concern with content uncovered a significant limitation of the model. Participants noted the important role of content in achieving motivation with the laboratory. Implementation in many computing disciplines would be restricted by a lack of content and instructors lacked the time, experience, and/or confidence to create new laboratory material. A solution to the content issue is beyond the scope of this study and should be the subject of future research. Several innovative ideas were proposed by the panel for an open source wiki or a peer reviewed online library of laboratory content.

Round Two questionnaire format implemented a five point Likert scale to provide greater discrimination in determining consensus. While the panel reached an overall consensus, the level of consensus for attention and relevance remained low in round two. Instructors tied acceptable attention and relevance to rigor and simplicity. The concern about content persisted. Ideas introduced earlier for creating and managing laboratory content were expanded in the panel's second round comments.

Several conclusions about motivation and learning in the laboratory emerged. Most were consistent with ARCS motivation theory and reflected the practical experience of the computing instructors participating in the panel. The laboratory must incorporate real-world tools, be driven by course work, and include assessments. Some panelists suggested a given lab could not be relevant to both novice and expert learners at the same time. Numerous panel recommendations were incorporated into the review material for Round Three.

Round Three consensus was high. The ratings for attention and relevance jumped to equivalent levels with confidence and satisfaction. The concerns about content limitations were not extended to all disciplines in Round Three. The panel concluded that some disciplines had adequate content to support ARCS motivation. Additional questions remained about the definitions of attention and relevance. The panel concluded more clarity was needed in the descriptions of how attention and relevance are implemented. The use of video tutorials for instructors and students was proposed to increase understanding of how the model incorporates motivation strategies.

The panel comments in Round Three were more optimistic and advisory. The positive tone was reflected in an increased favorable consensus overall and with respect to ARCS motivation strategies. The reactions of the computing instructors had shifted from cautiously positive in Round One to a clear consensus in the two final rounds. Hsu and Sandford (2007) noted that the median score is favored when using a Likert scale. The increase in median score from four to five across the board between Rounds Two and Three indicated a solid positive consensus for the ARCS – supported laboratory design.

What are the reactions of experienced computing education instructors to the ARCS – supported web-based combined laboratory in terms of adaptability, practicality, and usability? The initial reactions of the panel reflected the content concerns described earlier. The time and effort required to find or create content was the key issue. Perceptions about content persisted to a lesser degree after Round One. Issues of adaptability, practicality, and usability across disciplines emerged as new concerns. By the final round the panel concluded that a web-based combined laboratory model was adaptable, practical, and usable contingent on appropriate content for the chosen discipline and student population.

Round One reactions were varied as would be expected from a diverse panel of experts. Many instructors were concerned with the availability of content and others described adequate content and positive experiences with laboratories in their disciplines. Consensus for adaptability was highest, with practicality and usability close behind.

The panel observed that the laboratory was not completely adaptable, practical, or usable for all computing courses. Some questioned the usefulness of the combined laboratory format in programming courses, while others suggested the format could be adapted in their programming classes. A clear set of conclusions did not emerge in the first round.

Round Two consensus for adaptability and practicality were higher than usability. Favorable perceptions were often contingent on appropriate content. Some suggested the laboratory was not adaptable to non-computing courses or students. Concern was expressed about the cost in time and effort to incorporate ARCS motivation strategies.

The relatively low overall consensus indicated a persistent lack of confidence in the adaptability of the model across disciplines. Additionally, positive reactions were contingent on specific conditions. Conclusions based on the instructors' reactions were still not clear after the second round. The low favorable rating of usability was an indicator of the concern with effort and time required by instructors in many disciplines to incorporate a combined laboratory in their computing classes.

Round Three experienced a noteworthy increase in consensus. With a few exceptions, the perceptions of the expert panel were also more favorable. Very few contingent reactions were noted; several instructors shared positive experiences with experiential learning activities. Others expressed confidence in the ARCS framework

Conclusions based on instructor reactions were clearer in the third round. While content limitations were implicit in perceptions, they did not overshadow the value of the laboratory in courses where content was available. The positive reactions and high level of consensus across the board indicated increased support for the laboratory. The panel arrived at a logical conclusion; the laboratory is adaptable, practical, and usable when content is appropriate to the course objectives and students. This was not an unreasonable expectation.

The content limitation expressed earlier was a key factor in panel perceptions of the combined laboratory model. The conclusions that emerged from instructor reactions were contingent on appropriate content. The expert panel offered numerous ideas to address the issues of creating, storing, sharing, and managing laboratory content.

What modifications are needed to improve the ARCS - supported web-based combined laboratory model in terms of perceived adaptability, practicality, and usability? Recommendations for improvements were limited in the first two rounds. Initially many recommendations were related to content. In subsequent rounds the focus was on curriculum, technology, and classroom concerns. As experienced in earlier discussions, conclusions based on adaptability, practicality, and usability did not become clear until the final round.

Round One recommendations addressed a variety of issues. Usability had the lowest scores and the greatest number of recommendations. Topics ranged from content to professional development. The recommendations did not lead to an obvious conclusion by the panel after the first round.

Round Two panel recommendations increased in number with most comments addressing adaptability. Usability, which was rated lowest in the second round generated relatively few recommendations. A theme did not emerge; the variety of recommendations reflected the diversity of experience in the panel. While the content issue was a factor in practicality recommendations, it was hardly mentioned with respect to adaptability and usability. The primary conclusion drawn from the second round was panel confidence. The instructors did not appear to consider the issues of adaptability, practicality, and usability overwhelming. Solutions to the challenges were close at hand and available to most instructors.

Round Three panel recommendations were fewer in number and denser. Some comments presented several issues and as many solutions. The recommendations reflected the confidence that emerged in the previous round and took on an advisory tone. The comments reflected the high level of consensus and a conclusion that the laboratory was adaptable, practical, and usable because most issues could be overcome by individual instructors.

Implications

The benefits of laboratory experiences are widely accepted in technology disciplines. Laboratories are in use and providing learners with important practice with real world computing hardware and software. The web-based combined laboratory model offers an innovative laboratory option for computing education students. The model was validated internally using pilot studies and expert review techniques. A panel of experienced computing instructors agreed the model is adaptable, practical, usable, and will support ARCS motivation strategies. External validation steps remain to be completed.

An important outcome from the study is the idea that working faculty can develop a simple laboratory model. It is possible for an experienced instructor to identify a shortfall in her/his academic program and with few resources create a relevant solution. Readily available design and development research methods may be applied to validate adaptability, practicality, and usability.

The only implementation of the model was during pilot study validation in local campus classrooms. The validation was limited in scope and did not address the impact of the laboratory on computing students. While this study was initiated to understand laboratory use with non-traditional students, the expert review by a diverse panel of computing instructors validated the model with respect to a wider population of students that included both traditional and non-traditional students.

At this point the implications for the web-based combined laboratory model are limited to local classroom learning environments. The development process, pilot studies, and Delphi panel provided rich data to inform instructional designers, program managers, and faculty with best practices for the design and implementation of computing laboratories using the web-based combined model. Numerous recommendations emerged from the analysis of development, validation, and enhancement data.

Recommendations

The primary recommendation for instructional designers, program managers, and faculty is to audit existing computing courses to determine the need for experiential learning. Additionally, it may be necessary to adjust the sequence of course objectives to accommodate laboratory flow and sequencing. Some courses may need to be extended to dedicate more time for complex hands-on learning activities. Skill building opportunities need to be introduced in computing programs to ensure students can use the word processing, spreadsheet, and database applications needed to complete laboratory projects. Further study will help determine the appropriate design of computing programs to incorporate application skill training.

Internal validation of the model should be extended. External validation is needed to determine to what extent the model meets learner needs. The impact of the laboratory model on computing student motivation and learning should be studied and further research is recommended to extend validation to online modalities.

The panel suggested combined laboratories may not be relevant outside computing courses. The adaptability of the model to other disciplines should be explored. Specifically, computer intensive fields like finance and accounting may benefit from use of the web-based combined laboratory model.

Several projects are recommended to enhance the implementation and use of the model. First, two brief instructional videos are needed, one for faculty and one for students. The videos will provide context specific instruction about how to implement and use the web-based combined laboratory model. Second, a virtual reality laboratory demonstration was suggested as a tool to improve laboratory adoption. This technology should be explored to determine if an avatar could be used to demonstrate web-based combined laboratory activities. Third, integrated tools are needed to assess student learning and provide immediate feedback during laboratory activities. Fourth, a guidebook is needed to support instructor and student implementation of the model. Instructional videos can provide an alternative to the guidebook. Finally, a web-based laboratory content management environment is needed to support the content needs of the web-based combined laboratory model.

The Delphi panel identified content availability as a significant limitation of the model. A future Delphi panel of experienced lab users and researchers is needed to identify issues and priorities in the development of such resources. The research will guide the development of an online resource that includes the open source, peer reviewed, and multimedia qualities proposed by the panel.

Summary

The goal was to design, validate, and enhance a web-based laboratory instructional design model (IDM). Computing education students use laboratories to gain hands-on skills, solve real-world problems, and gain a better understanding of technology concepts (Chao, 2010). Data from laboratory experiments provide concrete insight into the limitations of theories introduced in the classroom and reinforce the framework of a technical discipline (Corter et al., 2011; Konak et al., 2014). Laboratory exercises increase learner experience in the practice of experimentation while providing an opportunity to work in real computing environments (Wolf, 2010).

Access to expensive real-world computing equipment prepares students for work in a corporate setting. The pace of change in computing contributes to the difficulty employers experience in hiring graduates with the appropriate skills to fill open positions. Relevant laboratory exercises prepare students for new jobs (Choi et al., 2010; Lahoud and Krichen, 2010).

Several laboratory configurations have been implemented in computing education courses. *Hands-on laboratories* are maintained in local campus facilities. Students carry out experiments while in the presence of real experimental equipment (Ma & Nickerson, 2006). Hands-on laboratories are expensive to maintain and have accessibility and flexibility restrictions (Chao, 2010; Choi, Lim, & Oh, 2010; Wolf, 2010).

Many institutions have explored web-based laboratories as a way to reduce costs and expand learner access to laboratory facilities. Students enter web-based laboratory classes through the Internet and are remote from the experimental equipment. Simulation and remote laboratories are the primary implementations for web-based laboratory classes (Corter et al., 2011).

Web-based simulation laboratories use software rather than real experimental hardware to replicate laboratory experiments. Simulation is inexpensive, models real equipment, allows student control of the laboratory environment, and facilitates multiple observations of the experimental process (Rutten et al., 2012). Simulation laboratories lack fidelity and oversimplify the experimental environment (Abdulwahed & Nagy, 2011; Chen, 2010; Wolf, 2010).

Web-based remote laboratories allow learners to experiment in an authentic computing environment using real computer hardware and software with significantly lower operating expenses than hands-on laboratories (Uludag et al., 2012). Remote laboratories can be shared among multiple learners without temporal or physical restrictions (Wolf, 2010). Although remote laboratories use real equipment they are considered too complex for novice learners.

A *combined web-based laboratory* blends the benefits of simulation and remote laboratories into a single laboratory environment. Hands-on, simulation, and remote laboratories when used alone have difficulty providing a full range of experiential learning opportunities (Abdulwahed & Nagy, 2011). A web-based combined laboratory provides several modes of laboratory experimentation within a uniform software environment, which allows learners to build knowledge by progressing through increasingly difficult activities at their own pace.

Additional studies were recommended to address the cognitive benefits of web-based laboratories in meeting learner goals (Corter et al., 2011). Research into laboratory preferences suggested further research was needed to determine the benefits of web-based laboratories with respect to different student populations (Lahoud and Krichen, 2010). Comprising 42% of the total U.S. enrollment in 2010, non-traditional students are an important sector of the undergraduate population (NCES, 2011).

Non-traditional students are over 25 with job, family and community commitments that compete with academics for their time, money, and energy (Rowen-Kenyon, Swan, Deutsch & Gansneder, 2010). The academic needs of non-traditional students are unique. Computer based formative learning materials that promote learner control and progress evaluations are preferred by non-traditional students (Newman & Clure, 2012). Web-based course materials allow influence over the time, location, and duration of learning to accommodate student schedules and support motivation (Joliffe et al., 2012).

Non-traditional learners bring a distinctive challenge to web-based laboratory design. Universal Design (UD) guidelines for non-traditional learners recommended web-based designs that account for the backgrounds, characteristics, and needs of diverse students (Rao, 2012). Relevant web-based laboratory designs must align with learner’s needs and goals (Green, 2012; Joliffe et al., 2012).

This research focused on model development, validation, and use (Richey & Klein, 2014). IDMs assist with matching the learning process with the context (Branch & Kopcha, 2014). Clearly defined models describe the application of procedures to the development of education resources. Instructional designers and instructors use models as conceptual tools to visualize, direct, and manage the creation of teaching and learning materials.

Procedural design methods were used to design the model. The process began with analysis activity and proceeded through specification of the learning environment to the development of components. The development process resulted in a web-based combined laboratory that integrated computer based learning, simulation, and remote laboratory components (Green, 2012). The Keller (2010) ARCS model of motivation was incorporated as a framework for the model design.

Motivation is associated with goal setting, achievement, and learning (Driscoll, 2005; Kim & Frick, 2011). The Keller (2010) model of motivation consists of four categories necessary for motivating learners; Attention, Relevance, Confidence and Satisfaction (ARCS). The ARCS model provides a structure for designing and implementing course materials that motivate learners. Validation was a natural part of the design process and was continued at every stage of development including implementation (Richey, 2005).

Design and development research methods guided validation of the model with respect to the development process, components, and use (Branch & Kopcha, 2014; Gibbons et al., 2014; Richey & Klein, 2014). The validation process examined the extent to which the model was adaptable, practical, usable, and supported motivation (Richey, 2005; Richey & Klein, 2007). Internal validation used pilot studies and expert review techniques to confirm the integrity of the model and its use, (Richey & Klein, 2014).

Three pilot tests examined the completeness and sequencing of the components. The pilot studies implemented a four unit database design laboratory prototype. One unit was presented each week for four weeks. A three round Delphi expert review extended the validation results of the pilot tests (Richey, 2005).

A diverse panel of experienced computing instructors was selected to provide a range of perspectives of instructional strategies, classroom settings, and expertise. Incremental adjustments to the model were applied after each round of the Delphi based on expert recommendations. A revised model was promulgated at the beginning of each new round. The iterative nature of the Delphi process allowed participants to think critically and generate data that informed enhancements to the laboratory design.

Several conclusions emerged during the study. A review of laboratory studies indicated students benefitted from the use of laboratories in undergraduate studies. Achievement was higher among students who had simulation and remote laboratory preparation. Students learned effectively in web-based laboratory environments.

An instructional design and development process informed revisions to promote motivation and learning in the ARCS-supported web-based combined laboratory model. The flow, relevance and completeness of the components were validated during pilot studies. Expert review by a panel of computing instructors from diverse backgrounds validated the model's ability to support motivation in the context of attention, relevance, confidence, and satisfaction.

The primary reaction to the model of the computing instructors in the Delphi panel was a concern about the availability of laboratory content. The time and effort required to find or create content was a key issue. The panel concluded the laboratory is adaptable, practical, and usable when appropriate content is available.

After three rounds of review the issues of adaptability, practicality, and usability were not considered overwhelming by the panel. Solutions to challenges were seen as close at hand and available to most instructors. The Delphi panel validated and enhanced the model with respect to adaptability, practicality, usability, and motivation. The internal validation steps extended understanding by examining a variety of conditions including alternative settings, different learners, novice and expert designers, diverse content areas, and assorted delivery strategies (Richey & Klein, 2007). While the study did not provide concrete answers to issues, it did uncover innovative applications and important concerns to guide future research.

Appendix A

NOVA SOUTHEASTERN UNIVERSITY
Office of Grants and Contracts
Institutional Review Board

MEMORANDUM

To: Michael Green

From: Ling Wang, Ph.D.
Institutional Review Board

Date: Jan. 27, 2015

Re: *Non-Traditional Computing Education Student Motivation and Learning in a Web-Based Combined Laboratory*

IRB Approval Number: wang01151503

I have reviewed the above-referenced research protocol at the center level. Based on the information provided, I have determined that this study is exempt from further IRB review. You may proceed with your study as described to the IRB. As principal investigator, you must adhere to the following requirements:

1) CONSENT: If recruitment procedures include consent forms these must be obtained in such a manner that they are clearly understood by the subjects and the process affords subjects the opportunity to ask questions, obtain detailed answers from those directly involved in the research, and have sufficient time to consider their participation after they have been provided this information. The subjects must be given a copy of the signed consent document, and a copy must be placed in a secure file separate from de-identified participant information. Record of informed consent must be retained for a minimum of three years from the conclusion of the study.

2) ADVERSE REACTIONS: The principal investigator is required to notify the IRB chair and me (954-262-5369 and 954-262-2020 respectively) of any adverse reactions or unanticipated events that may develop as a result of this study. Reactions or events may include, but are not limited to, injury, depression as a result of participation in the study, life-threatening situation, death, or loss of confidentiality/anonymity of subject. Approval may be withdrawn if the problem is serious.

3) AMENDMENTS: Any changes in the study (e.g., procedures, number or types of subjects, consent forms, investigators, etc.) must be approved by the IRB prior to implementation. Please be advised that changes in a study may require further review depending on the nature of the change. Please contact me with any questions regarding amendments or changes to your study.

The NSU IRB is in compliance with the requirements for the protection of human subjects prescribed in Part 46 of Title 45 of the Code of Federal Regulations (45 CFR 46) revised June 18, 1991.

Cc: Protocol File

3301 College Avenue • Fort Lauderdale, FL 33314-7796 • (954) 262-5369
Fax: (954) 262-3977 • Email: *inga@nsu.nova.edu* • Web site: www.nova.edu/cwis/ogc

Appendix B

Database Design Laboratory Overview

Objective	CBL (Skill Soft©)	Simulation (You Tube©)	Remote Laboratory (Tool Wire©)
Practice Database Design Principles.	In the Logical and Physical Design Methodologies module: Complete the *Define Entities and Attributes for ERD Modeling* topic.	*Entity Relationship Diagram (ERD) Training Video* (Baldazzi, 2013). *Visio 2010 Parts Crows Foot ERD (Jozwik, 2010).*	Using the SkillSoft Job Aids in the *Logical and Physical Design Methodologies* course identify Brocadero Online University entities, attributes, and relationships. Create a rough ERD.
Create an ERD using MS Visio.	In the Logical and Physical Design Methodologies module: Complete the *Model Relationships in the ERD* topic.	*ERD Entity Relationship Diagram Cardinality Relationships Part 1* (TekLek411, 2012). *Working With Entity Relationship Diagrams (Telombardi, 2012)*	Complete your Visio ERD from the previous lab exercise. Add cardinality, and primary keys. Draw a key based ERD. Complete the ERD with attributes of interest for all entities.
Create database tables using MS Access.	In the Logical and Physical Design Methodologies module: Complete *The Physical Database Design Implementation* module.	MS Access Tutorials and Training: *Creating a Database Table; The Database Window; and, Working With Database Tables Parts 1, 2, and 3* (LearnMAccess, 2010).	Using the ERD you created in the previous laboratory exercise create tables for a Brocadero Online University database in Access 2010.
Normalize MS Access database tables to third normal form.	In the Logical and Physical Design Methodologies module: Normalizing the Database Design/Complete the *Defining Normalization and its levels* module.	*Normalisation Demonstration* (McNichol, 2009).	Normalize the Brocadero Online University tables to the third normal form.

Appendix C

Demographic and Experience Survey

For the research study entitled *Non-Traditional Computing Education Student Motivation and Learning in a Web-Based Laboratory*

1. Name:

2. Please enter an address where the informed consent documents can be sent:

3. What is Your Highest Degree?

- Bachelor
- Masters
- Doctorate

Other (please specify)

4. What is Your Primary Computing Education Discipline?

- Networking
- Database
- Programming

Other (please specify)

5. Where do you teach?

- Community College
- Traditional University
- Non-Traditional University

Other (please specify)

6. What is Your Primary Teaching Format?

- Classroom
- Online
- Blended

7. How long have you taught computing education courses?

- ○ 1-3 years
- ○ 4-6 years
- ○ More than 6 years

8. How many different computing education courses do you teach?

- ○ 1-3
- ○ More than 3

9. How many computing education courses do you teach per year?

- ○ 1-3
- ○ More than 3

10. Do you use laboratories with your computing education classes?

- ○ Yes
- ○ No

11. If you use labs what is the primary format?

- ○ Hands-on
- ○ Web-based

12. If you use labs how long have you used them?

- ○ 1-3 years
- ○ 4-6 years
- ○ More than 6 years

Appendix D

Participant Solicitation Email Template

My name is Michael Green and I am an undergraduate computing instructor. I am also a student at Nova Southeastern University (NSU) working on a PhD degree in Computing Technology in Education. My dissertation research study is entitled *Non-Traditional Computing Education Student Motivation and Learning in a Web-Based Combined Laboratory*.

Please consider participating in my study. I am looking for higher education instructors from all computing disciplines to participate in a Delphi panel review of the web-based combined laboratory model I designed. Your unique experience teaching computing will add important depth and perspectives to the panel.

If you are interested in participating in the study please complete the demographic survey at the link below. The survey will help me analyze the diversity in the Delphi panel composition and guide participant selection. I will respond with further instructions about the study.

https://www.surveymonkey.com/s/mgcomped

The attached informed consent form is for your review and provides information about your rights as a participant. If you choose to participate in the study I will email you directly regarding the informed consent procedures.

The abstract of my research proposal is listed below:

Hands-on experiential learning activities are an important component of computing disciplines. Laboratory environments provide learner access to real world equipment for completing experiments. Local campus facilities are commonly used to host laboratory classes. While campus facilities afford hands-on experience with real equipment high maintenance costs, restricted access, and limited flexibility diminish laboratory effectiveness. Web-based simulation and remote laboratory formats have emerged as low cost options, which allow open access and learner control. Simulation lacks fidelity and remote laboratories are considered too complex for novice learners.

A web-based combined laboratory format incorporates the benefits of each format while mitigating the shortcomings. Relatively few studies have examined the cognitive benefits of web-based laboratory formats in meeting computing students' goals. A web-based combined laboratory model that incorporates motivation strategies will be developed to address non-traditional computing education students' preferences for control of pace and access to learning. Internal validation of the laboratory model will be conducted using Delphi expert review techniques. A panel of instructors from diverse computing backgrounds will review the laboratory model. Panel recommendations will guide enhancement of the model design.

The Delphi process will take place via email and involve successive rounds of questioning. During each round participants will review information about the model and provide feedback through a questionnaire process. The composition and sources of communication within the Delphi panel will be anonymous.

At the end of each round the researcher will collate the responses and provide every member of the panel with a statement of the collective position. Additionally a summation of comments will make every participant aware of the range of opinions and the reasons underlying those opinions. Finally, the model will be revised based on panel recommendations. The process will continue until the panel reaches the desired level of consensus or three rounds. The time requirement for panel members is approximately 1 – 1.5 hours per round. The study will begin in early March 2015 and continue for six weeks.

Please feel free to contact me if you have questions about the study. Thank you for considering this request to participate in my computing education research. I look forward to hearing from you.

Sincerely,

Michael Green
415-235-4234
mg1724@nova.edu

Appendix E

Delphi Panel Round One Instructions

Dear:

Thank you for participating in this Delphi panel. The goal of the panel is to validate, and enhance a web-based combined laboratory model designed to support computing education students' motivation and learning. Your expertise in computing instruction will guide your role in validating the model and improving the model components.

During each round participants will review descriptive materials related to the current model and provide feedback through a questionnaire. The source of panel communications will be confidential. The researcher will collate the responses and provide every member of the panel with a statement of the collective position. Additionally a summation of comments will make every participant aware of the range of opinions and the reasons underlying those opinions. The model will be revised based on panel recommendations. Three rounds of review will be completed during the study unless consensus is reached earlier. The review materials and questionnaire associated with each round will take approximately one-hour to complete.

Instructions for the first round

Please read the attached review materials. They include a description of the web-based combined laboratory model and an overview of ARCS motivation strategies. The model description includes a summary of the design, components, and implementation options. The motivation strategies consist of techniques for designing attention, relevance, confidence, and satisfaction into a web-based combined laboratory environment.

Round One Questionnaire Instructions

After reviewing the attached round one material please read the questionnaire instructions below and complete the online Round One questionnaire at the link provided. Be as candid and specific as possible. Your responses and recommendations will guide the enhancements I make to the model design.

When evaluating the laboratory model you are asked to consider the following criteria: *adaptability* (i.e. how useful is the model in a range of design projects and what is its capacity to accommodate a variety of content, delivery systems, and instructional strategies?); *practicality* (i.e. is the model cost effective and can it function well with different academic cultures, resources, course environments, and learner populations?); *usability* (i.e. can the model be implemented by expert and novice designers under most conditions); and, *ARCS motivation strategies* (i.e. does the model design facilitate incorporation of materials that will gain/maintain learners' attention, provide a relevant learning experience, foster confidence, and satisfy learners' goals?).

Link to the Round One Questionnaire

https://www.surveymonkey.com/s/MGDelphi1

In order to complete the study in the shortest possible time frame I will be grateful if you post your reply within a week of receiving this email.

Thank you again for your participation in this study.

Warm regards,

Mike

Appendix F

Round One Review Materials

Laboratory Overview

Hands-on experiential learning activities are an important component of computing disciplines. Laboratory environments provide learner access to real world equipment for completing experiments. Local campus facilities are commonly used to host laboratory classes. While campus facilities afford hands-on experience with real equipment high maintenance costs, restricted access, and limited flexibility diminish laboratory effectiveness. Web-based simulation and remote laboratory formats have emerged as low cost options, which allow open access and learner control. Simulation lacks fidelity and remote laboratories are considered too complex for novice learners.

A web-based combined laboratory incorporates the benefits of each format while mitigating the shortcomings. Relatively few studies have examined the cognitive benefits of web-based laboratory formats in meeting computing students' goals. A web-based combined laboratory model that incorporates motivation strategies is under development to address non-traditional computing education students' preferences for control of pace and access to learning. Internal validation of the laboratory model components will be conducted using Delphi expert review techniques. A panel of instructors from diverse computing backgrounds will review the laboratory model. Panel recommendations will guide enhancement of the model design.

Objective	CBL (Skillsoft© Activities)	Simulation (You Tube©)	Laboratory Activity (Tool Wire©)
Practice Database Design Principles.	*Define Entities and Attributes for ERD Modeling* topic.	*Entity Relationship Diagram (ERD) Training Video* (Baldazzi, 2013).	Create a rough ERD using Visio 2010.
Create an ERD using MS Visio.	*Model Relationships in the ERD* topic.	*Working With Entity Relationship Diagrams (Telombardi, 2012)*	Complete your Visio ERD for Brocadero Online University from the previous lab exercise.
Create database tables using MS Access.	*The Physical Database Design Implementation* module.	*Working With Database Tables Parts 1, 2, and 3* (LearnMAccess, 2010).	Using your ERD create tables for a Brocadero Online University database in Access 2010.
Normalize MS Access database to 3rd normal form.	*Defining Normalization and its levels* module.	*Normalisation Demonstration* (McNichol, 2009).	Normalize the Brocadero Online University tables.

Table 1 Database Design Laboratory Overview

A laboratory course based on the web-based combined laboratory model is organized into several units. Each unit covers one primary concept and addresses a single experiential learning objective. Computer Based Learning (CBL) modules, simulation learning, and laboratory activities are completed to fulfill the requirements of the unit objective.

For example, table 1 presents an overview of a web-based database design laboratory that was piloted in an introductory database concepts course. Database design content for the course was divided into units that covered the concepts of entities and attributes, entity relationship diagrams, database tables, and normalization. The laboratory facilitated learning the concepts, practicing the design skills, and creating a simple relational database using a popular database program.

The web-based combined laboratory model is composed of several components including learning objectives, computer based learning (CBL) modules, simulation activities, and laboratory exercises. Ideally, existing objectives and materials can be used with the model to design and implement a laboratory course. Off the shelf resources include commercially available training tools such as Skillsoft, YouTube© videos, and web/computer tools to complete skill based activities. Instructor developed objectives and materials are readily compatible with the laboratory model when off-the-shelf resources are not available.

Components

Objectives
Laboratory objectives guide the course design. Typically laboratory activities are integrated into a computing course using or building on existing course objectives. For example the database design laboratory described previously was created to support completion of existing course objectives, which guided students' design and development of a working relational database. When learning objectives are not available the instructor should develop objectives to guide the desired skill development.

Computer Based Learning Modules
Computer Based Learning (CBL) allows self-paced review of the important concepts associated with each learning objective. For example the computer based learning modules used in the first unit of the database design laboratory described the role of entities and attributes in preparing an entity relationship diagram (ERD). CBL activities are self-paced and learners can view, repeat, or skip each module as desired. Learners who understand the concepts provided by the CBL are ready to proceed to simulation.

Simulation Demonstration
Simulation provides a demonstration of the skill directed by the unit objective. In the first unit of the database design laboratory a YouTube© video was used to show learners how to develop entities and attributes from business rules. Simulation activities are self-paced and learners can view, repeat, or skip each module as desired. Learners who understand

the skill demonstrated by the simulation demonstration are ready to proceed to the laboratory activity.

Laboratory Activity

The CBL and simulation demonstration prepare the learner to demonstrate the desired skill in a laboratory activity. In the case of the first unit of the database design laboratory students developed entities and attributes from a business scenario provided by the instructor. This activity can be used to provide scaffolding and a formative evaluation of learning. All of the units of the laboratory may be completed and repeated as needed.

Resources

The model can adapt to a wide variety of existing open source, commercial, or instructor produced materials. Resources are limited only by an instructor's imagination. Many institutions subscribe to commercial resources such as Skillsoft©, LabSim©, or Toolwire©, which are easily integrated into the Web based combined laboratory. Additionally, there are a significant number of open source tools available at education websites and YouTube©. Instructor produced videos or presentations are also appropriate for use with the model. The model is designed for implementation by instructors with varied teaching experience in a variety of learning formats.

Implementation

Laboratory implementation is intended to be flexible. Although the web-based laboratory model was envisioned as a stand-alone learning tool for remote use by students, it can be used in a classroom setting. An instructor's judgment is the best guide for appropriate laboratory implementation. To date the laboratory model has been piloted only in a local campus database concepts classroom under the guidance of the researcher. While the pilot studies confirmed the completeness and flow of materials little is known about how the model will function in different courses and learning formats.

An important goal of the study is the internal validation by expert instructors of potential laboratory model implementations in a variety of computing courses, delivery formats, institutional settings, and levels of instructor expertise. The composition of this Delphi panel is quite diverse. Participants in this panel represent a broad cross section of computing disciplines, institutions, and experience. Honest and constructive inputs by panel members will provide varied perspectives on laboratory implementations and a broad consensus of its adaptability, practicality, usability, and capacity to motivate computing education students.

Motivation Strategies

Using the ARCS model framework the web-based combined laboratory model incorporates computer based learning, simulation, and remote hands on activities. Motivation and learning require *attention* be captured and maintained through a variety of materials that make the learning experience stimulating and interesting. The laboratory employs computer based learning, multimedia, and hands-on exercises to provide instructional variety to maintain attention. *Relevance* is gained by meeting individual needs in ways that are useful in the lives of the students. The topics presented in the laboratory are closely aligned with objectives students must achieve to succeed in the course. Learners gain *confidence* through completion of activities in which they control their own success. Confidence results from the presentation of laboratory materials in manageable units that allow students' control over the time and pace of learning. Ultimately, *satisfaction* comes from achieving a challenging computing education learning objective through completion of a laboratory assignment. If attention relevance and confidence are achieved students will be motivated to learn. Satisfaction is required to ensure a continuing desire to learn.

Attention

- Attention is required for motivation to occur
- Teaching and learning techniques should be changed frequently
- Use a variety of engaging materials, resources, and presentation modalities

Relevance

- Include activities that match students' learning goals
- Align activities with course objectives

Confidence

- Provide clear objectives
- Frequent instructor feedback
- Give learners control of pace and access to activities
- Offer frequent opportunities for assessment that demonstrate success

Satisfaction

- Use a rigorous and objective assessment process
- Provide opportunities to apply new skills
- Include as system for providing intrinsic and extrinsic rewards

Appendix G
Delphi Round One Questionnaire

Instructions: When evaluating the laboratory model you are asked to consider the following criteria: adaptability (i.e. how useful is the model in a range of design projects and what is its capacity to accommodate a variety of content, delivery systems, and instructional strategies?); practicality (i.e. is the model cost effective and can it function well with different academic cultures, resources, course environments, and learner populations?); usability (i.e. can the model be implemented by expert and novice designers under most conditions); and, ARCS motivation strategies (i.e. does the model design facilitate incorporation of materials that will gain/maintain learners' attention, provide a relevant learning experience, foster confidence, and satisfy learners' goals?).

1. *Adaptability:* If you were to implement this laboratory model as designed to a computing education course you teach would it adapt to the content, delivery, format, and instructional strategies required to help students gain the knowledge and skills needed to achieve the stated learning outcomes?

○ **Yes**

○ **No**

2. If no please briefly explain your response to the previous question.

3. *Practicality:* Would it be practical for you to implement this laboratory model as designed in a computing education course you teach?

○ **Yes**

○ **No**

4. If no please briefly explain your response to the previous question.

5. *Usability:* Do you think you have the skills needed to implement this laboratory as designed in a computing education course you teach?

○ **Yes**

○ **No**

6. If no please briefly explain your response to the previous question.

7. *Attention:* Do you think the laboratory model as designed can gain and maintain learner attention?

- Yes
- No

8. If no please briefly explain your response to the previous question.

9. *Relevance:* Do you think the laboratory model as designed can provide relevant computing education activities?

- Yes
- No

10. If no please briefly explain your response to the previous question.

11. *Confidence:* Do you think your students will gain confidence in their computing skills from using the laboratory model as designed?

- Yes
- No

12. If no please briefly explain your response to the previous question.

13. *Satisfaction:* Do you think your students will be satisfied after completing a laboratory class using this model as designed?

- Yes
- No

14. If no please briefly explain your response to the previous question.

15. What enhancements would you recommend to improve the adaptability, practicality, usability, and/or ARCS motivation design of the current laboratory model?

Done

Appendix H

Delphi Panel Round Two Instructions

Dear:

Thank you for participating in this Delphi panel. In response to comments in the Round 1 questionnaire I have added detail about the laboratory model below and in the attached revision to the model overview.

The goal of this Delphi panel is to validate, and enhance a web-based laboratory instructional design model (IDM). Models assist with matching the learning process with the context. Instructors use IDMs as conceptual tools to visualize, direct, and manage the creation of teaching and learning materials. Models work best when matched with the corresponding context. A model's validity is linked closely to how well it meets the intended context.

This Delphi panel is composed of a diverse group of computing instructors from a variety of disciplines, academic backgrounds, and institutions. Some teach only online or in the classroom and others teach in a variety of formats. Each brings a unique perspective to the validation process.

The internal validity of this model will be based on your perceptions as expert instructors of the adaptability, practicality, usability, and ARCS motivation qualities of the model components and your ability to implement the model in classes you teach. An additional outcome of this Delphi exercise is a determination of the level of consensus among the panel members with respect to the qualities of the web-based laboratory components.

Statement of the Collective Position of the Delphi Panel

Based on responses to the questionnaire at the end of round one the panel had an overall 81% positive perception of the web-based combined laboratory model. There was a unanimous consensus that the model is *adaptable* and nearly unanimous consensus that students can gain *confidence* (92%) and *satisfaction* (85%) when using the model. *Practicality* (77%), *usability* (77%), *attention* (69%), and *relevance* (69%) had lower levels of consensus. See the attached panel comments for additional details.

Directions for the Second Round

Review materials have been updated for Round Two. Please look them over prior to completing the questionnaire. They include a summation of participants' comments and an overview of model components and motivation strategies, which were revised based on participant feedback.

Round Two Questionnaire Instructions

After reviewing the instructions below please answer the online Round Two questionnaire at the link provided. Be as candid and specific as possible. Your responses and recommendations will guide enhancements to the model design.

When evaluating the laboratory model you are asked to consider the following criteria: *adaptability* (i.e. how useful is the model in a range of design projects and what is its capacity to accommodate a variety of content, delivery systems, and instructional strategies?); *practicality* (i.e. is the model cost effective and can it function well with different academic cultures, resources, course environments, and learner populations?); *usability* (i.e. can the model be implemented by expert and novice designers under most conditions); and, *ARCS motivation strategies* (i.e. does the model design facilitate incorporation of content that will gain/maintain learners' attention, provide a relevant learning experience, foster confidence, and satisfy learners' goals?).

Link to the Round Two Questionnaire

https://www.surveymonkey.com/s/MGDelphi2

In order to complete the study in the shortest possible time frame I will be grateful if you post your reply by Monday, March 31st.

Thank you for your continued participation in the study.

Warm regards,

Mike

Appendix I

Round Two Revised Review Materials
(New and revised content is in italics)

Laboratory Overview

Hands-on experiential learning activities are an important component of computing disciplines. Laboratory environments provide learner access to real world equipment for completing experiments. Local campus facilities are commonly used to host laboratory classes. While campus facilities afford hands-on experience with real equipment high maintenance costs, restricted access, and limited flexibility diminish laboratory effectiveness. *Web-based laboratory formats have emerged as low cost options, which allow open access and learner control.*

Web-based simulation laboratories are accessed through the Internet and use software to replicate laboratory experiments. Simulation software is inexpensive, models real laboratory equipment, and facilitates multiple observations of the experimental process. Reduced fidelity is a constraint of simulation software.

Web-based remote laboratories allow learners to experiment in an authentic computing environment using real computer hardware and software with significantly lower operating expenses than hands-on laboratories. Students manipulate experimental equipment remotely and laboratories can be shared among multiple learners without temporal or physical restrictions. Remote laboratories have been criticized for a lack of physical presence and functionality that is too complex for novice learners.

Web-based combined laboratories integrate multiple laboratory formats and learning resources. An advantage of combined laboratories is flexible access to a range of resources that allow students to review and rehearse experimental concepts prior to completing a laboratory assignment. In a combined laboratory format web-based simulation was shown to help novice learners prepare for more complex hands-on laboratories.

A laboratory course based on the web-based combined laboratory model is organized into several units. Each unit covers one primary concept and addresses a single experiential learning objective. Computer Based Learning (CBL) modules, simulation learning, and laboratory activities are completed to fulfill the requirements of the unit objective.

For example, table 1 presents an overview of a web-based database design laboratory that was piloted in an introductory database concepts course. *The goal of laboratory was support for students to practice and learn database design skills while applying best practices. Content for the course was divided into units that covered the concepts of entities and attributes, entity relationship diagrams, database tables, and normalization.* The laboratory facilitated learning the concepts, practicing the design skills, and creating a simple relational database using a popular database program.

Objective	CBL (Skillsoft© Activities)	Simulation (You Tube©)	Laboratory Activity (Tool Wire©)
Practice Database Design Principles.	*Define Entities and Attributes for ERD Modeling* topic.	*Entity Relationship Diagram (ERD) Training Video* (Baldazzi, 2013).	Create a rough ERD using Visio 2010.
Create an ERD using MS Visio.	*Model Relationships in the ERD* topic.	*Working With Entity Relationship Diagrams (Telombardi, 2012)*	Complete your Visio ERD for Brocadero Online University from the previous lab exercise.
Create database tables using MS Access.	*The Physical Database Design Implementation* module.	*Working With Database Tables Parts 1, 2, and 3* (LearnMAccess, 2010).	Using your ERD create tables for a Brocadero Online University database in Access 2010.
Normalize MS Access database to 3rd normal form.	*Defining Normalization and its levels* module.	*Normalisation Demonstration* (McNichol, 2009).	Normalize the Brocadero Online University tables.

Table 1 Database Design Laboratory Overview

The web-based combined laboratory model is composed of several components including learning objectives, computer based learning (CBL) modules, simulation activities, and laboratory exercises. Ideally, existing objectives and materials can be used with the model to design and implement a laboratory course. Off the shelf resources include commercially available training tools such as Skillsoft©, YouTube© videos, and web/computer tools to complete skill based activities. Instructor developed objectives and materials are readily compatible with the laboratory model when off-the-shelf resources are not available.

Components

Objectives

Laboratory objectives guide the course design. Typically laboratory activities are integrated into a computing course using or building on existing course objectives. For example the database design laboratory described previously was created to support completion of existing course objectives, which guided students’ design and development of a working relational database. When learning objectives are not available the instructor should develop objectives to guide the desired skill development.

Computer Based Learning Modules
Computer Based Learning (CBL) allows self-paced review of the important concepts associated with each learning objective. *For example the Skillsoft © computer based learning modules used in the first unit of the database design laboratory described the role of entities and attributes in preparing an entity relationship diagram (ERD) and included periodic learning assessments. Students who are familiar with the concepts may choose not to complete the CBL modules or the instructor may want to use a pretest to determine who must complete the CBL modules.* These activities are self-paced and learners can view, repeat, or skip each module as desired. Learners who understand the concepts provided by the CBL are ready to proceed to simulation.

Simulation Demonstration
Simulation provides a demonstration of the skill directed by the unit objective. In the first unit of the database design laboratory a YouTube© video was used to show learners how to develop entities and attributes from business rules. Simulation activities are self-paced and learners can view, repeat, or skip each module as desired. Learners who understand the skill demonstrated by the simulation demonstration are ready to proceed to the laboratory activity.

Laboratory Activity
The CBL and simulation demonstration prepare the learner to demonstrate the desired skill in a laboratory activity. In the case of the first unit of the database design laboratory students developed entities and attributes from a business scenario provided by the instructor. This activity can be used to provide scaffolding and a formative evaluation of learning. *Teamwork can be integrated into the laboratory activity to increase learner discussion and reflection.* All of the units of the laboratory may be completed and repeated as needed.

Resources
This component can be challenging as organized validated content is not readily available. The model can adapt to a wide variety of existing open source, commercial, or instructor produced materials. Resources are limited only by an instructor's imagination. Many institutions subscribe to commercial resources such as Skillsoft©, LabSim©, or Toolwire©, which are easily integrated into the Web based combined laboratory. Additionally, there are a significant number of open source tools available at education websites and YouTube©. Instructor produced videos or presentations are also appropriate for use with the model. The model is designed for implementation by instructors with varied teaching experience in a variety of learning formats.

Implementation

Laboratory implementation is intended to be flexible. Although the web-based laboratory model was envisioned as a stand-alone learning tool for remote use by students, it can be used in a classroom setting. An instructor's judgment is the best guide for appropriate laboratory implementation. To date the laboratory model has been piloted only in a local campus database concepts classroom under the guidance of the researcher. While the pilot studies confirmed the completeness and flow of materials little is known about how the model will function in different courses and learning formats.

An important goal of the study is the internal validation by expert instructors of potential laboratory model implementations in a variety of computing courses, delivery formats, institutional settings, and levels of instructor expertise. The composition of this Delphi panel is quite diverse. Participants in this panel represent a broad cross section of computing disciplines, institutions, and experience. Honest and constructive inputs by panel members will provide varied perspectives on laboratory implementations and a broad consensus of its adaptability, practicality, usability, and capacity to motivate computing education students.

Motivation Strategies

Using the ARCS model framework the web-based combined laboratory model incorporates computer based learning, simulation, and remote hands on activities. Motivation and learning require *attention* be captured and maintained through a variety of materials that make the learning experience stimulating and interesting. The laboratory employs computer based learning, multimedia, and hands-on exercises to provide instructional variety to maintain attention. *Relevance* is gained by meeting individual needs in ways that are useful in the lives of the students. The topics presented in the laboratory are closely aligned with objectives students must achieve to succeed in the course. Learners gain *confidence* through completion of activities in which they control their own success. Confidence results from the presentation of laboratory materials in manageable units that allow students' control over the time and pace of learning. Ultimately, *satisfaction* comes from achieving a challenging computing education learning objective through completion of a laboratory assignment. If attention relevance and confidence are achieved students will be motivated to learn. Satisfaction is required to ensure a continuing desire to learn.

Attention

- Attention is required for motivation to occur
- Teaching and learning techniques should be changed frequently
- Use a variety of engaging materials, resources, and presentation modalities
- *Incorporate scenarios such as what-if situations*

Relevance

- Include activities that match students' learning goals
- Align activities with course objectives
- *Integrate content that supports instructional goals*
- *Use vendor and user group resources*

Confidence

- *Design exercises that can be completed successfully by students*
- Provide clear objectives
- Frequent instructor feedback
- Give learners control of pace and access to activities

- Offer frequent opportunities for assessment that demonstrate success

Satisfaction

- Use a rigorous and objective assessment process
- Provide opportunities to apply new skills
- Include as system for providing intrinsic and extrinsic rewards

Appendix J

Delphi Panel Round 1 Participants' Comments

This is the complete and unedited list of comments submitted by Delphi Panel members in the Round 1 questionnaire between March 11 and March 23, 2015. Round 1 was closed on March 24th and no further comments were received or accepted.

Adaptability: *If you were to implement this laboratory model as designed to a computing education course you teach would it adapt to the content, delivery, format, and instructional strategies required to help students gain the knowledge and skills needed to achieve the stated learning outcomes?*

I answered "yes", but I would like to add some additional information. This is becoming more feasible each day due to access to a variety of tools, many of which are coming at no-cost to the student. As an instructor that focuses on software development, I would like to see the tools become more web-based in nature so to eliminate potential challenges with software version and many technical challenges that may arise from student-installed software.

I would need to review actual pedagogical material and presentation in order to answer this question with confidence. Assuming I was designing the content - I can answer yes this laboratory model would adapt quite well to courses I have taught and currently teach. I am not familiar with the ToolWire. The design indicates that learners who understand the material are ready to move on to the next component - I assume there would be some evaluation process included in the component.

Practicality: *Would it be practical for you to implement this laboratory model as designed in a computing education course you teach?*

Integration of the wide variety of online tools is a challenge, not just in initial creation of a task oriented lab module, but in the ongoing maintenance. The online resources would need to be curated and the integration step would need to be simple "point and click" for the instructor and not need extensive testing.

Do not have a course that matches close enough to the objectives.

You do not need remote laboratories (Computer Based Learning) in my programming courses. Students can perform many tasks on their computers.

Usability: *Do you think you have the skills needed to implement this laboratory as designed in a computing education course you teach?*

I do not know what skills are needed. In innovating we never know what we do not know and so we have to learn along the way. This takes much more time than we initially think, because innovators have to be optimists. So to create a body of instructors who are willing to innovate with the notion of a web-based combined lab there would need to be components already tested that could be linked together like Legos. So it is a matter of skills AND time.

I am responding cautiously "no" to the usability because I feel that I would need more professional development on the CBL and simulations activities. In my experience, I have been actively implementing my course using constructivist learning theory. While the laboratory component is standardized among instructors for my particular course, I would love to focus on CBL and simulation learning in an effort to minimize passive instruction.

Not sure: This question opens issues around ease of use, time to implement/update, and if it is agile enough to change over time. Effort versus practicality is a real consideration. If time is invested to design can it be reused, or repurposed for the future.

I believe so - but it would be a challenge to create all the materials rather than using or adapting existing material.

Attention: *Do you think the laboratory model as designed can gain and maintain learner attention?*

IF the web-based combined lab is designed to show results WITHOUT assuming the learner has read and studied a textbook then the experience might be attractive enough to engage the overly casual student learner. Students that this kind of tool is aimed at would be those who do NOT have the qualities of focus and persistence that characterizes traditional students aimed at higher learning. These students would have the resources to pursue the costly local campus learning experience. To make the web-based combined learning experience available to the mass market of learners who do not have the resources for local campus learning there would need to be an Open Source movement for learning, like the Open Source movement for computer code. Practitioners in the field are enticed to contribute their skills and time to build an infrastructure that is available to all comers. The attractiveness of such a project could be made evident IF there is a technology chasm to be hurdled that merits the attention of the best and the brightest to solve. For example, applying BIG DATA or Virtual Reality or Augmented Reality to the cause of revolutionizing learning would be a "Man on the Moon" societal challenge that would attract youthful talent and energy and passion.

What-if type scenarios need to be incorporated to gain and maintain learner attention.

Depends on the quality, veracity, and applicability of the course components, such as the YouTube© videos and skillsoft courses, to the course subject. If materials are dated or less relevant, student attention will fade.

It depends. My experience is students do not watch video clips longer than 5-6 minutes. The sample videos were too long for example. The hands-on components will definitely retain their attention.

Relevance: *Do you think the laboratory model as designed can provide relevant computing education activities?*

The current model is conceptual model. What survey examples of resources (YouTube©, etc...) have been done and what examples of integrated "solutions" exist in order to enable us to assess the feasibility of the web-based combined lab proposal? I do not yet see the difference between web-based simulation and remote lab and the web-based combined model. What elements of the local campus lab are in the web-based combined model?

I answered "no" with the caveat that the course design must support instructional goals and students must be able to achieve prescribed goals. One of the challenges I find as an instructor is having students follow procedures that correspond to professional software engineering best practices. I believe that labs, as constructed, allow for more flexibility than I currently prefer. For the labs to be relevant, I would like to see more controls put in place that force a student to solve a solution on best practices, not a student's practices. I believe the model provides for it, but instructors look for details because of instilled values and experience. The overarching goals presented is great, but expanding on practical details will be necessary for wide-adoption of the proposed model.

However, a learning/teaching technique is not what contains the relevance component of pedagogy. The content presented has to be relevant. Using the example in the document, if a student is designing an ERD, logical model, and physical model for an irrelevant database concept like employees, projects and departments I don't think the content has relevance even if the delivery mechanism does. I'm not sure I understand the separation here between the relevance of the content and the relevance of the learning modality based on the document.

Not for every computing education activities. This depends on the task and course. A better definition of computing education is needed to answer this question. It is more relevant for some areas (e.g., Excel Skills) than others (programming)

Confidence: *Do you think your students will gain confidence in their computing skills from using the laboratory model as designed?*

Yes and no. If the tool exists and is bullet-proof the students would certainly benefit from using it. However, for a database course a good deal of the benefits of the proposed model could be accomplished by simply having the students convert a simple single spreadsheet to an Access database just by doing the import process. They can choose their own spreadsheet or download a .csv file from a web-based database, like calories from a fast food vendor or BLS data from the government. Then ask them to create a form, query and report. The concepts of ERD and normalization could be discussed and even applied after the student was successful with the initial database creation process. Take advantage of the ease of use programmed into the latest commercial products in the market today, products that are either already in the core set of products available to most students on PC's. So, students do not need to use something new to accomplish a good portion of their learning task IF instructors are creative in using what is already available or what is available for a 30 day trial .

Satisfaction: *Do you think your students will be satisfied after completing a laboratory class using this model as designed?*

Yes and no. The students would certainly be more pleased if they felt they had learned something useful and done something that others do not do. But, actually getting hands on experience with commercially available products would be better than hands on with something that the students might never see again.

A tangible outcome that has a "touch-and-feel" experience is needed for learner satisfaction.

Again - the content here is what will provide the satisfaction. Busy work does not produce a satisfied student.

Recommendations for Enhancement

I am left with the impression that this design is scalable at a moment's "notice". I would think moment's "notice" would be student/class dependent. So, from this perspective, I find the design good.

Create a conceptual model for mapping the use of current proprietary products or Open Source products to learning objectives of entire primary, secondary, trade school and college curricula. Create "hands-on" lab opportunities for courses that do not have labs associated with them today. Give students the opportunity to jump in and play with learning labs even without the oversight of a teacher. Enable them to get oversight or questions answered by other users, peers. This stuff should NOT be rocket science to create or use. Teachers would be the biggest bottleneck to creating web-based combined lab experience anyway, since they are NOT technology savvy and are generally NOT passionate entrepreneurial types. So the teachers would NOT be good mentors or coaches in general for these kinds of hands on learning experiences. Kids do NOT have access to a teacher to learn how to play a video games at the highest levels. The youth culture is geared to motivate and encourage achievement and persistence and focus, even collaboration. So why would hand-on labs try to re-invent a motivating learning eco-system? Develop the model so interested teachers on an Open Source basis could curate a web-based hands-on experience for students.

I strongly believe that many rank-and-file educators care about the details of implementing this model successfully. "What's the benefit for me?" is a question I see asked repeatedly when implementing new models. I don't think this is a new concept, so the question becomes, "where in computing education does this model need to be implemented?" There are some disciplines where an on-campus laboratory needs to be translated to a remote-access environment. This study may be able to shine a light on those specific areas. A working curriculum model should be demonstrated to provide a basis for instructors to improve upon and utilize in their work.

-Keeping the laboratory model relevant with current technology changes.
-A consideration is using a "rapid development" software model with the ability to adjust the model based on feedback from all stakeholders.

From a usage perspective, the model needs to have a complete real application feel.
Some visuals

Assume that it is scenario based
I have no suggestions. I do particularly like where the students are asked to create a basic database design - implementing a practical skill is vital!

when possible, integration with materials that are from or related to the target tool or program, or somehow connected to the vendor (perhaps from a user group)...would increase student buy-in to the program.

To make the model's use as simply as possible. Students would appreciate that and their learning expereinces would be just great. Also, I would recommend to use reliable computer systems (portals) that would prevent/avoid problems during their useage.

I would like more detail - it is hard to make judgements on the efficacy of the model without some potential samples of the approach. Much is dependent on execution.

None. The lab, as described, coincides almost exactly with most similar Lab exercises developed for basic database courses that I teach and have taught in the past, and it should work well (i.e., should be effective as noted in the replies above.) The minimally specific description of the Lab itself, however, leaves some room for doubts on my part, as I can think of trivial exercises that could very well conform to that description, as well as pretty complex ones. The degree of complexity of the chosen exercise could compromise some of my replies above, particularly as to the Relevance and Satisfaction parameters.

This is a difficult question to answer. The order of the model phases is important for example. Overall, I would recommend involving teamwork.

Appendix K

Delphi Round Two Questionnaire

When evaluating the laboratory model you are asked to consider the following criteria: adaptability (i.e. how useful is the model in a range of design projects and what is its capacity to accommodate a variety of content, delivery systems, and instructional strategies?); practicality (i.e. is the model cost effective and can it function well with different academic cultures, resources, course environments, and learner populations?); usability (i.e. can the model be implemented by expert and novice designers under most conditions); and, ARCS motivation strategies (i.e. does the model design facilitate incorporation of materials that will gain/maintain learners' attention, provide a relevant learning experience, foster confidence, and satisfy learners' goals?).

1. Please enter your name

2. The laboratory model is adaptable (i.e. the laboratory model can adapt to the content, delivery format, and instructional strategies of a computing course I teach):

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
○	○	○	○	○

3. Comments/Suggestions for Enhancement

4. The laboratory is practical (i.e. it would be practical for me to implement this laboratory model in a computing course I teach):

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
○	○	○	○	○

5. Comments/Suggestions for Enhancement

6. The laboratory is usable (i.e. I could implement this laboratory model in a computing course I teach):

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
○	○	○	○	○

7. Comments/Suggestions for Enhancement

8. The laboratory model can be used to present content in ways that gain and maintain computing students' attention:

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
○	○	○	○	○

9. Comments/Suggestions for Enhancement

10. The laboratory model can be used to present content in a relevant context:

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
○	○	○	○	○

11. Comments/Suggestions for Enhancement

12. The laboratory can support the development of student confidence:

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
○	○	○	○	○

13. Comments/Suggestions for Enhancement

14. Student satisfaction can be achieved with this laboratory:

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
○	○	○	○	○

15. In addition to your comments above, what specific thoughts, questions, and/or recommendations do you have for advancing the adaptability, practicality, usability and ARCS motivation capability of the web-based combined laboratory model? What suggestions do you have for improving instructor skills and access to materials? What best practices can you offer to minimize the time needed to implement a web-based laboratory in a course you teach?

Done

Appendix L

Delphi Panel Round Three Instructions

Dear:

I am grateful for your continued participation in this Delphi panel. This is the final round. You have provided many relevant enhancements and recommendations for implementation of the model in a variety of learning environments. Thank you.

The model is used by instructors to match the learning content with the course context. Instructors have the latitude with this model to implement a laboratory that aligns the content with theory and objectives.

An important outcome of a Delphi panel review is the identification of important issues. Laboratory content limitations arose as a significant issue in both round one and round two of this panel. While much content is available, it is clear that much more is needed across computing disciplines. The cost, time, and skill required to create new content is a significant limitation of widespread adoption of this laboratory model and perhaps any model. The issue will be acknowledged and discussed in my study.

Statement of the Collective Position of the Delphi Panel

Based on the Likert scale of 1-5 used in the Round 2 questionnaire the panel's collective mean rating of the model was 4.2 of 5. The *Confidence* (mean 4.4) and *satisfaction* (mean 4.3) ratings showed the highest level of consensus. A*daptability* (mean 4.2), *Practicality* (mean 4.2), *usability* (mean 4.1), and *relevance* (mean 4.1) had slightly lower levels of consensus. *Attention* (mean 4) had the lowest rating. The collective *median* rating was 4 of 5. See the attached panel comments for additional details.

Directions for the Third Round

Review materials have been updated for Round Three. Please look them over prior to completing the questionnaire. A summation of the participants' round two comments and revised model overview are attached to this email.

Round Three Questionnaire

After reviewing the instructions below please answer the online Round Three questionnaire at the link provided. Be as candid and specific as possible. Your responses and recommendations will guide enhancements to the model design.

When evaluating the laboratory model you are asked to consider the following criteria: *adaptability* (i.e. how useful is the model in a range of design projects and what is its capacity to accommodate a variety of content, delivery systems, and instructional strategies?); *practicality* (i.e. is the model cost effective and can it function well with different academic cultures, resources, course environments, and learner populations?); *usability* (i.e. can the model be implemented by expert and novice designers under most conditions); and, *ARCS motivation strategies* (i.e. does the model design facilitate incorporation of content that will gain/maintain learners' attention, provide a relevant learning experience, foster confidence, and satisfy learners' goals?).

Link to the Round Three Questionnaire

https://www.surveymonkey.com/s/MGDelphi3

In order to complete the study in the shortest possible time frame I will be grateful if you post your reply by Monday, April 13.

Thank you for your continued participation in the study.

Warm regards,

Mike

Appendix M

Delphi Panel Round 2 Participants' Comments

This is the complete and unedited list of comments submitted by Delphi Panel members in the Round 2 questionnaire between March 24 and April 6, 2015. Round 2 was closed on April 6th. All panel members participated.

***Adaptability**: The laboratory model is adaptable (i.e. the laboratory model can adapt to the content, delivery format, and instructional strategies of a computing course I teach).*

No enhancements for this application-type of course, however for a networking course the use of virtual machines is a superior way of learning for hands-on labs. Unlike simulations, virtual machines allow for a full range of commands.

Very important: LM is adaptable to various computer devices used by students.

It would seem that the lab activity should always have an objective with it.

Use of the model depends on the hosting institution's policy -- some may allow adding such software elements, while other won't.

Learning to install and manage a tool set locally (on single user systems) is also part of the learning process. Lacking this knowledge will result in significant skill gaps for IT majors. So the lab model should comprehend this scenario.

I teach on ground: programming (C/C++, Java), software engineering, systems analysis and design, and database. I think this model could be adapted to meet the needs of these courses assuming that content could be created or is available.

Depends on the relevancy of the laboratory model to the course material, and how close the assignment is to the real software, hardware, or methodology being presented to the student over the course of the class. Simulations are OK, but the real benefit will be realized when the student experiences the same user interface.

While I selected Agree, I also feel Strongly Agree can be a response. The ARCS model is a learning model which from my perspective is adaptable to learning models on "any" topic.

It is possible to adapt a course to use the web-based lab model. Students have smartphones to access online calculators or dashboards. This is simpler than using PC-based html tools that may be too complicated for students.

The model certainly has promise in terms of adaptability. Given the varying methods of classroom instructions (i.e. online, on-ground, blended, etc.), I see value in adapting each component to a given class format. In reviewing the proposed model a second time, questions around differentiation and scale remain. How would this model differentiate itself from mainstream concepts, such as flipped classroom? Further, would the model translate to larger institutions that are more traditional and have a larger classes? The model appears to have an implied limitations that may be clarified in a future revision of this model.

The model is seems to be adaptable from my perspective. My biggest concern is how the ease of adaptability for the instructor. I believe the trick will be to allow the instructor's method of teaching to be fully integrated into a model that mixes technology and a strong instructor learning led teaching environment. User acceptance by instructors and students may be tricky because the needs of the two groups are not always aligned. Basic classroom structures must be in place within this framework. The flexibility to adapt change is constraint preparation time and the tools flexibility.

Practicality**:** *The laboratory is practical (i.e. it would be practical for me to use this model to create laboratory activities for a computing course I teach).*

Yes, this is a very practical, multi-faceted approach.

LM is practical because of its simple-to-use by students.

I don't see any issues

Again - content is the driver here. It would be practical if a good amount of relevant content was available for the different learning objectives in the courses I teach. If content were not available then practicality would be more limited as I would have to create the content at some instructional design expense in terms of financial and time resources.

We don't have access to actual labs currently for most courses. In the example given, one of the assignments was to create a Visio diagram for an Access database. This could be done via access to Visio and Access in Toolwire, but I would recommend that the faculty go through an example or encourage the students to do a "create a DB" walk-through so they understand the basics of how each tool works. In many of the courses we teach, the required tools are not available, or not up to date (I had students in the capstone course use free WIX rather than Java and other programs available on Toolwire for website development}. To build a successful flowchart and database, students must understand how the tool works.

I am not sure how practical the ARCS learning model might be. From my perspective, the assumption is that all learners will come to this model with at least similar learning levels. Additionally, just because the ARCS might be a good model does not mean that it will outweigh costs of learning: especially, when up against traditional and more economical models.

Thinking of using Survey Monkey to do real time surveys and statistical analysis of students class responses. Thinking of using www.SpreadsheetConverter.com to create online spreadsheet calculators that can simulate an instrument dashboard or a server dashboard. Use Excel to simulate range of control settings.

No incentive from the university to create such a tool. If there was an Open Source industry movement that would provide UI standards to simplify development and reward investments in such development.

My indecision is primarily based on the existing tools available for web-based lab assignments. In my courses, which are primarily programming in nature, I place emphasis on the design of a solution, in addition to computer code. There are a number of tools out there for visualizing design, but the tools available for implementing code in a web-based format remaining in a developing phase. Attempts have been made to translate integrated development environments online, but many of these have features that may present a challenge in tracking authenticity of an individual's own work.

The opportunity to have near real experiences is a huge advantage when learning new concepts and ideas. Much like flight simulators students will have the opportunity to experience the application of concepts and practice what is learned. They become proficient during the learning experience.

I have designed two online courses including many labs created based on a model very similar to the described model. So, it is practical for me to use the model. Although it takes time to do, it is feasible. Again, I don't think that every single laboratory activity should include all three components of the model.

Usability: *The laboratory is usable (i.e. I could implement a laboratory using this model in a computing course I teach).*

I don't see any issues

Yes - thanks for the details.

Some courses will require access via real gui to a local or remote lab based on real hardware. For example, the Networking concentration courses will have access to Cisco and VMware labs among other tools.

Assuming the model's technology is incorporated into the coursework design, then yes, it could be implemented. However, and again the operative comparative is "by expert and novice designers under most conditions". The learning model design would need to prevail over the technology which supports the design.

There's a certain limitation as to the tools I can utilize, but I can implement laboratory activities using existing software (i.e open source compilers, operating systems, etc.).

However, I see an opportunity to incorporate web-based features provided that development reaches a level of maturity as to provide an authentic environment.

I thought you did an especially good job here.

Attention: *The laboratory model can be used to present computing content in ways that gain and maintain students' attention.*

If you are going need show the students why this activity and the outcome are important. I don't see this.

Depending on the choice of actual lab exercises. If trivial, students will quickly lose interest.

Depending on the course yes. If I was using this model to reach objective on inference rules for functional dependency in database design - I think the interactive back and forth might be the only way to keep a students attention. This may be a product of the dryness of the topic rather than the delivery model!

Yes in the example given, but not in general without some tie-in to what the student will see if they were doing the work in the real world. Also, some of these assignments could take more than 5 weeks. Suggest tying courses together where a larger assignment could span 4-5 weeks with deliverables. Finally, evein with available simulation or lab software, the technology does not easily divide itself into digestible chunks that fit into weekly assignments. Course designers should go through the materials and give the faculty some options for accessing and presenting material. When I created VMware courses, for example, I converted labs into weekly assignments to meet specific weekly course objectives, which was not easy.

The assumption is that learners will engage with such lab models. My viewpoint is that this would depend on how much of the coursework is lab content driven. But in general I think the lab model would engage students: that is if the lab model is user friendly enough and does not frustrate students.

Students may be attracted to engage with a video game-like experience that is not too complex or require lots of reading and preparation. They would be engaged to fiddle and play.

I would suggest expanding Table 1 to provide a more detailed accounting of the activities associated with a unit. This appears to be a basic outline of a lesson plan. To convince practitioners of this model, a certain level of detail, along with how it relates to the ARCS model is critical. If analyzed correctly, it appears that the CBL & simulation is designed to encompass the "Attention" component. The simulation is also designed to support "Relevance". Finally, the laboratory is mean to support "Relevance", but also "Confidence" and "Satisfaction". As an educator, I see learning objectives integrated into typical lesson plans, and an opportunity to integrate motivational strategies may be helpful to visually how ARCS integrates into the laboratory model.

I love your comment about grabbing attention to motivate students...sometimes very hard to do with some subject matter but very true!

Simulation or virtualization provides the opportunity to turn theoretical knowledge into practical knowledge. Retention and understanding of subject matter increase as students are able to apply what is learned. Different touch points help to reinforce knowledge.

Based on my experience, students do not watch long videos training videos. For example, incorporating Linda tutorials into my online courses has not been successful. I think a good laboratory model should incorporate hands-on experience and theory somehow together. I prefer a model which meshes theoretical knowledge with hand-on experience reinforced with reflection.

Relevance: *The laboratory model can be used to present computing content that is relevant to computing students.*

Again it doesn't explain why this important for the learner.

Challenging exercises should be incorporated to maintain students attention, else they will follow path of least resistance.

The lab model should not be generalized as applicable to all computing education. There are certain courses where it is very applicable. For example, Web programming. In other cases, beginners can use this approach, but not for advanced level learners.

If the tie into real world applications (uses and tools) is achieved, then this model could be very useful. If not, students will not take the time to look at the material and in some cases may skip the assignment and take the hit on points.

If by computing students you mean IT driven students, I am inclined to agree. However, non IT driven students, I am inclined to disagree.

Yes. The model can be used to present overall context and drill down to needed detail.

There is a wealth of content and information that can be provided to students to enhance the learning experience as they progress through a lab assignment. In addition to being relevant, content can be selected to gather attention to the importance of a given concept.

Absolutely

The terms "computing content" and "computing students" are too general. The model will work for some course types, but not to others. IT also depends whether the courses is online or not.

Confidence: *The laboratory can support the development of computing students' confidence.*

still doesn't get at why it is important. Also, where and how they are going to use it.

Again, depending on the complexity of the chosen exercises.

Yes - especially if the assessment is reasonable.

Depends how close the model can get to a real implementation.

If by computing students you mean IT driven students, I am inclined to agree. However, non IT driven students, I am inclined to disagree.

Yes. Progressive accomplishment will build confidence, especially if the student is not a textbook learner, but is a kinetic learner.

The proper laboratory model can be effective to develop confidence in a computing concept. I believe there is a research opportunity to quantify confidence & satisfaction levels using this laboratory model versus competing models, as applicable.

Students seeing practical application will always build confidence.

If the lab is strongly integrated with subject matter and students use the tools provided confidence will increase with "practice."

The model includes some type of scaffolding built-in. Students with limited technical skills can benefit from it.

Satisfaction: *Computing students' satisfaction can be achieved with this laboratory.*

In addition to your comments above, what specific thoughts, questions, and/or recommendations do you have for advancing the adaptability, practicality, usability and ARCS motivation capability of the web-based combined laboratory model? What suggestions do you have for improving instructor skills and access to materials? What best practices can you offer to minimize the time needed to implement a web-based laboratory in a course you teach?

In my opinion, the LM is the gateway to enhancing computer education for our students in all modalities, including: face-to-face, online, hybrid, and MOOC

It seems it focuses solely on the out come with out the theory or the application being emphasized

Reducing complexity, of customizing the web based model, for teachers will be the main impediment for adoption.

In terms of adaptability, I believe the model is adaptable to almost any pedagogical goal - but the real question is the practicality of doing so. IF there is not material already available and accessible, then it will have to be designed. Design costs money, resources, time and may differ based on learner population. It may not be practical to do the design work to create the learning artifacts for a low enrollment course. Assessing cost effectiveness would be a product of development costs and potential revenue generation. The model itself, without respect to content, appears to be very usable. Whether or not it could be used as a framework for novice and experienced designers depends completely on the content which will vary from course to course. As an example, creating good artifacts to simulate assembly of a personal computer vs learning artifacts to simulate how pointers to structures are used in vectors of structures goes from the concrete to the abstract. Simulation for the abstract is more difficult and will require more experience. I understand that there is a difference in the model and the implementation of the model. I don't have any problems with the model - I do however think that implementing the model will be more difficult - if not impossible - with some course requirements that I teach without significant investment in design resources.

In my opinion, success of the model depends on current, up to date examples and assignments that are relevant to solving real (not hypothetical) problems in the IT workplace. Improving instructor skills? Give workshops to IT faculty on Toolwire and skillsoft with specific examples of their use in UoP courses. I tried TODAY to access toolwire to help a student in her next course, but since I am not currently teaching a course using Toolwire, I do not have a valid link or access. I can get to Skillsoft from the Library page but not Toolwire, and without a published syllabus or upcoming course, the program will not let me access the materials. Best practices? Give early access to faculty to develop their methodologies. share best practices in CAMs or an onlineforum among faculty who teach a current course. No sense reinventing the wheel. Have some materials to choose from based on outside commercial sources that have been at least partially vetted...students only touch skillsoft and toolwire when they have to.

Generally speaking yes. However, and again, providing the labs are not utilized as an end all be all type of learning tool. Hence, humans, require some to significant amounts of human interaction.

Need to create a movement that attracts students and faculty to develop such web-based labs.

Computing education is wide field that encompasses many disciplines, ranging from the use of office productivity software to theoretical computer science. My primary recommendation is that you expand the model to perhaps fit existing methods of curriculum planning, such as lesson plans and frameworks. Mapping ARCS to a lesson plan would create value add and a note to an instructor as indicators to observe during the course of instruction. From a practical perspective, an instructional content exchange for computer education would be useful. There are many tutorial-based materials, but are there materials to support the educator? Having a research-based resource for educators would make it easier to implement lessons that support the laboratory model. In terms of web-based laboratories, practicality is the key consideration when implementing them in a computer education course. Is the product mature enough to support learning objectives? Will it integrate with existing learning management systems? Can collaboration occur, whether among students and/or instructors? Can the lab support fair and accurate assessments? With the continued evolution of web-based applications, labs will become more realistic and authentic. In the meantime, can the model be adapted to not include web-based elements to support existing technologies? I see this model working with existing course structures with the slow integration of web-based tools coming as maturity develops. Finally, how does this lab model differ from trending pedagogies? Or is this model is designed to be used with existing practices?

Very impressed so far with how you have your study organized! Keep up the good work.

To minimize the time needed to implement a web-based laboratory think about using wizards in a cloud environment which would provide a common platform that is similar for all courses. If implementation includes lab content a structure platform would help to minimize time to modify the basic lab. When labs are structured from a template they would be easier for instructor to developed/modify laboratory.

Appendix N

Round Three Revised Review Materials
(New and revised content is in italics)

Laboratory Overview

Hands-on experiential learning activities are an important component of computing disciplines. Laboratory environments provide learner access to real world equipment for completing experiments. Local campus facilities are commonly used to host laboratory classes. While campus facilities afford hands-on experience with real equipment high maintenance costs, restricted access, and limited flexibility diminish laboratory effectiveness. Web-based laboratory formats have emerged as low cost options, which allow open access and learner control.

Web-based simulation laboratories are accessed through the Internet and use software to replicate laboratory experiments. Simulation software is inexpensive, models real laboratory equipment, and facilitates multiple observations of the experimental process. Reduced fidelity is a constraint of simulation software.

Objective	CBL (Skillsoft© Activities)	Simulation (You Tube©)	Laboratory Activity (Tool Wire©)
Practice Database Design Principles.	*Define Entities and Attributes for ERD Modeling* topic.	*Entity Relationship Diagram (ERD) Training Video* (Baldazzi, 2013).	Create a rough ERD using Visio 2010.
Create an ERD using MS Visio.	*Model Relationships in the ERD* topic.	*Working With Entity Relationship Diagrams (Telombardi, 2012)*	Complete your Visio ERD for Brocadero Online University from the previous lab exercise.
Create database tables using MS Access.	*The Physical Database Design Implementation* module.	*Working With Database Tables Parts 1, 2, and 3* (LearnMAccess, 2010).	Using your ERD create tables for a Brocadero Online University database in Access 2010.
Normalize MS Access database to 3rd normal form.	*Defining Normalization and its levels* module.	*Normalisation Demonstration* (McNichol, 2009).	Normalize the Brocadero Online University tables.

Table 1 Database Design Laboratory Overview

Web-based remote laboratories allow learners to experiment in an authentic computing environment using real computer hardware and software with significantly lower operating expenses than hands-on laboratories. Students manipulate experimental equipment remotely and laboratories can be shared among multiple learners without temporal or physical restrictions. Remote laboratories have been criticized for a lack of physical presence and functionality that is too complex for novice learners.

Web-based combined laboratories integrate multiple laboratory formats and learning resources. An advantage of combined laboratories is flexible access to a range of materials that allow students to review and rehearse experimental concepts prior to completing a laboratory assignment. In a combined laboratory format web-based simulation was shown to help novice learners prepare for more complex hands-on laboratories.

A laboratory course based on the combined laboratory model is organized into several units. Each unit covers one primary concept and addresses a single experiential learning objective. Computer Based Learning (CBL) modules, simulation learning, and laboratory activities are completed to fulfill the requirements of the unit objective.

For example, table 1 presents an overview of a web-based database design laboratory that was piloted in an introductory database concepts course. *The laboratory supported students' practicing and learning of database design skills and best practices.* Content for the course was divided into units that covered the concepts of entities and attributes, entity relationship diagrams, database tables, and normalization. The laboratory facilitated learning the concepts, practicing the design skills, and creating a simple relational database using a *real-world relational* database program.

The web-based combined laboratory model is composed of several components including learning objectives, computer based learning (CBL) modules, simulation activities, and laboratory exercises. Ideally, existing objectives and materials can be used with the model to design and implement a laboratory course. Off the shelf resources include commercially available training tools such as Skillsoft©, YouTube© videos, and web/computer tools to *support* skill based activities. Instructor developed objectives and materials are readily compatible with the laboratory model when off-the-shelf resources are not available.

Components

Objectives

Learning objectives guide laboratory course design. Typically laboratory activities are integrated into a computing course using or building on existing course objectives. *The purpose of the laboratory is to support experiential learning or learning by doing and the instructor should insure one experiential learning objective per module. For example the previously described database design laboratory was created to support completion of existing experiential learning objectives such as "Create an ERD using MS Visio©", which guided students' in one step of the process of designing and developing a working relational database. When experiential learning objectives are not available the instructor will need to develop the objectives required to guide the desired skill development.*

Computer Based Learning Modules
Computer Based Learning (CBL) allows self-paced review of the important concepts associated with each learning objective. For example the Skillsoft © CBL modules used in the first unit of the database design laboratory described the role of entities and attributes in preparing an entity relationship diagram (ERD) and included periodic learning assessments. *CBL is designed primarily for novice learners. Completion of the CBL modules by all students is not a requirement of the model. Advanced students who are familiar with the concepts may elect not to complete the CBL modules. If the laboratory is led by the instructor a pretest may be used to determine who must complete the CBL modules. Available on the web,* these activities are self-paced and learners can view, repeat, or skip each module as desired. Learners who understand the concepts provided by the CBL are ready to proceed to simulation.

Simulation Demonstration
Simulation provides a demonstration of the skill directed by the unit objective. In the first unit of the database design laboratory a YouTube© video was used to show learners how to develop entities and attributes from business rules. *While novice learners find simulation particularly helpful, completion by all students is not a requirement of the model.* Simulation activities are self-paced and learners can view, repeat, or skip each module as desired. Learners who understand the skill demonstrated by the simulation demonstration are ready to proceed to the laboratory activity.

Laboratory Activity
CBL and simulation prepare the novice learner to demonstrate the desired skill in a laboratory exercise. In the case of the first unit of the database design laboratory students developed entities and attributes from a business scenario provided by the instructor. *Each laboratory exercise can be used to provide scaffolding and a summative evaluation of the students' achievement of the learning objective for the unit.* Teamwork can be integrated into the laboratory activity to increase learner discussion and reflection. All of the units of the laboratory may be completed and repeated as needed.

Resources
This component can be challenging as organized validated content *may not be* readily available. The model can adapt to a wide variety of existing open source, commercial, or instructor produced materials. Resources are limited only by an instructor's imagination. Many institutions subscribe to commercial resources such as Skillsoft©, LabSim©, or Toolwire©, which are easily integrated into the Web based combined laboratory. Additionally, there are a significant number of open source tools available at education websites and YouTube©. Instructor produced videos or presentations are also appropriate for use with the model. The model is designed for implementation by instructors with varied teaching experience in a variety of learning formats.

Implementation

Laboratory implementation is intended to be flexible. Although the web-based laboratory model was envisioned as a stand-alone learning tool for remote use by students, it can be used in a classroom setting. An instructor's judgment is the best guide for appropriate laboratory implementation. To date the laboratory model has been piloted only in a local campus database concepts classroom under the guidance of the researcher. While the pilot studies confirmed the completeness and flow of *components* little is known about how the model will function in different courses and learning formats.

Motivation Strategies

Using the ARCS model framework the web-based combined laboratory model incorporates computer based learning, simulation, and remote hands on activities. Motivation and learning require *attention* be captured and maintained through a variety of materials that make the learning experience stimulating and interesting. The laboratory employs computer based learning, multimedia, and hands-on exercises to provide instructional variety to maintain attention. *Relevance* is gained by meeting individual needs in ways that are useful in the lives of the students. The topics presented in the laboratory are aligned closely with objectives students must achieve to succeed in the course. Learners gain *confidence* through completion of activities in which they control their own success. Confidence results from the presentation of *theory and content* in manageable units that allow students' control over the time and pace of learning. Ultimately, *satisfaction* comes from achieving a challenging computing education learning objective through completion of a laboratory assignment. If attention relevance and confidence are achieved students will be motivated to learn. Satisfaction is required to ensure a continuing desire to learn.

Attention

- Attention is required for motivation to occur
- *Make obvious the benefits of successful completion of the laboratory*
- Teaching and learning techniques should be changed frequently
- Use a variety of engaging materials, resources, and presentation modalities
- Incorporate scenarios such as what-if situations
- *Adapt activities to a variety of mobile computing devices*

Relevance

- Include activities that match students' learning goals
- Align activities with course *theory and* objectives
- *Incorporate real world scenarios, hardware, and software*
- Integrate content that supports instructional goals
- Use vendor and user group resources

Confidence

- *Design a series of short modules that can be completed successfully by students*
- Provide clear objectives
- Frequent instructor feedback
- Give learners control of pace and access to activities

- Offer frequent opportunities for assessment that demonstrate success

Satisfaction

- *Conduct a rigorous and objective assessment of the laboratory exercise component*
- Provide opportunities to apply new skills
- Include as system for providing intrinsic and extrinsic rewards

Appendix O

Delphi Round Three Questionnaire Instructions

When evaluating the laboratory model you are asked to consider the following criteria:*adaptability* (i.e. how useful is the model in a range of design projects and what is its capacity to accommodate a variety of content, delivery systems, and instructional strategies?); *practicality* (i.e. is the model cost effective and can it function well with different academic cultures, resources, course environments, and learner populations?); *usability* (i.e. can the model be implemented by expert and novice designers under most conditions); and, *ARCS motivation strategies* (i.e. does the model design facilitate incorporation of content that will gain/maintain learners' attention, provide a relevant learning experience, foster confidence, and satisfy learners' goals?).

1. Please enter your name

2. *Adaptability*: The laboratory model is adaptable (i.e. the laboratory model can adapt to the content, delivery format, and instructional strategies of a computing course I teach):

Not True	Slightly True	Moderately True	Mostly True	Very True
○	○	○	○	○

3. Comments/Suggestions for Model Enhancement

4. *Practicality*: The laboratory is practical (i.e. it would be practical for me to use this model to create laboratory activities for a computing course I teach):

Not True	Slightly True	Moderately True	Mostly True	Very True
○	○	○	○	○

5. Comments/Suggestions for Model Enhancement

6. *Usability*: The laboratory is usable (i.e. I could implement a laboratory using this model in a computing course I teach):

Not True	Slightly True	Moderately True	Mostly True	Very True
○	○	○	○	○

7. Comments/Suggestions for Model Enhancement

8. *Attention*: The laboratory model can be used to present computing content in ways that gain and maintain students' attention:

Not True	Slightly True	Moderately True	Mostly True	Very True
○	○	○	○	○

9. Comments/Suggestions for Model Enhancement

10. *Relevance*: The laboratory model can be used to present computing content that is relevant to computing students:

Not True	Slightly True	Moderately True	Mostly True	Very True
○	○	○	○	○

11. Comments/Suggestions for Model Enhancement

12. *Confidence*: The laboratory can support the development of computing students' confidence:

Not True	Slightly True	Moderately True	Mostly True	Very True
○	○	○	○	○

13. Comments/Suggestions for Model Enhancement

14. *Satisfaction*: Computing students' satisfaction can be achieved with this laboratory:

Not True	Slightly True	Moderately True	Mostly True	Very True
○	○	○	○	○

15. Comments/Suggestions for Model Enhancement

16. In addition to your comments above, what specific thoughts, questions, and/or recommendations do you have for
improving instructors' laboratory content design skills, increasing access to relevant laboratory materials for a course you teach, and/or best practices to minimize the time and effort required to implement a web-based laboratory in a course you teach?

Done

Appendix P

Delphi Panel Round 3 Participants' Comments

This is the complete and unedited list of comments submitted by Delphi Panel members in the Round 3 questionnaire between April 7 and April 21, 2015. Round 3 was closed on April 21. Twelve panel members participated.

Adaptability: *The laboratory model is adaptable (i.e. the laboratory model can adapt to the content, delivery format, and instructional strategies of a computing course I teach).*

If an IS&T course is Networking or Enterprise Security hands on experience would significantly help students relate to real world. The web-based lab could minimize the hurdles of gaining access to real equipment and learning the idiosyncracies of the equipment Would need to have split screen user interface to present on one screen high level concepts in flow chart or circuit diagram form and concurrently a low level screen to present progressive dashboards of instruments needing configuration. This would be similar to the user interface of various html WYSIWYG editors. Or synchronize screens between a PC for the big picture flowchart/circuit view and a smart phone for the dashboard view.

Its use is simple.

Looks good

Yes -- in particular, software application courses can use this model.

I am beginning to think that this LM might be more work that most students can find time for and/or have the capability to follow from A to Z and then apply it to coursework objectives.

Thinking it could be difficult to align one experiential learning objective to module. Some material will adapt better than others.

A step-by-step approach needs to be incorporated in to teaching very advanced concepts.

The latest revisions of the model, combined with the ARCS framework, provides for opportunities to develop students confidence in a subject. The thought that came to mind when reviewing the latest revision is that newer credentialing systems, such as badges, could be combined to provide students with micro-credentials that highlight learned concepts.

Practicality: *The laboratory is practical (i.e. it would be practical for me to use this model to create laboratory activities for a computing course I teach).*

Need to see what an inventory of existing laboratory modules might be for the specific courses (networking or enterprise security). Rather than create modules myself it would be most practical to participate in a Wiki so I could take existing modules and customize or enhance them and then contribute my value-added modules to the Wiki for others to use. To get something like this started someone just has to define a database architecture for inputs/outputs of "industry standard" computing and networking devices (switches, routers, gateways, firewalls, etc...) and software diagnostic commands/tools (PING, TRACERT, etc...). Then various labs could be created by instructors developing Excel Macros that calculate the values of the input settings of devices and produce the appropriate output states. These could be simplified for "ceteris paribus" learning (all other things being equal or unchanged). It would be a diagrammatic form of a multiple choice exercise or a simplified form of a simulation. I think of this as a "Dim Sum" lab, as opposed to a "Full Meal" lab. It is a small learning module that does not require much setup or study to create for the instructor and does not require much effort to setup and play with for students.

Absolutely! this model is an important step ahead towards all 4 learning modalities: face-to-face, online, hybrid, and MOOC.

It would need some adapting.

Again this just might depend on how well versed the student is in this area.

Lab information is generally available, but depends on which course. Some tools/labs are provided by the school and licensed on a per-course basis. Would be very true if you can guarantee access to the resources.

The key statement within the latest revision is: "Make obvious the benefits of successful completion of the laboratory" The importance of mapping to curriculum outcomes to course content is paramount, regardless the chosen instructional model. As higher education continues to respond to the demands of validating the value of a degree, the ability to objectively quantify learning is going to become more relevant. By mapping outcomes to course objectives, students and faculty will have a mutual understanding on how the course will progress. The ARCS framework now has additional clarity on the practicality. I believe that in additional mapping course objectives, the ARCS framework needs to mapped to a curriculum.

Again - it depends on the course. I don't know that there will ever be a 5 for such an absolute question.

Usability: *The laboratory is usable (i.e. I could implement a laboratory using this model in a computing course I teach).*

If a lab collaboration Wiki existed the web-based lab would be usable.

It is definitely usable in a computing my courses.

It would need some enhancement

I think it would be great to provide a LM/lab that is already established (installed) and all students would need to do is logon and complete. But I love the idea.

Have to make sure that supplementary assignments in places like tool wire or skillsoft do not confuse students. Faculty must guide students as to what to do and what not to do. As these supplements were designed independently, not for your specific course. Suggest that faculty create simple walk-through example that students can use lab/software tools.

The laboratory should be as realistic as possible. For example, all error output during operations should be trapped and provided to the user.

The web-based lab model is only limited by the maturity of the software. For instance, in a computer applications based course, online substitutes for productivity software (i.e. Google Drive and OneDrive) exist and can substitute for its desktop application equivalent. The potential for simulations and relevant learning tasks can be adapted. In other disciplines, time and synergy is needed to make web-based simulations available. However, this does not immediately disqualify the general laboratory model. The lab model, along with the ARCS framework, has potential and the benefit of being easy to implement.

i like the changes on making some things optional as dictated by the experience of the learner. I do think, however, that such optional components need to be determined by the instructor or the system in terms of pre-testing etc. Allowing students to self-select best on self efficacy judgements will result in an inconsistent skill level as the course progresses.

Attention: *The laboratory model can be used to present computing content in ways that gain and maintain students' attention.*

A simple lab "experience" would be interesting and engaging for the students. Aim to have several simple lab experiences per week.

Yes, it will gain and maintain students' attention.

It would need some customization

In my experience, students perform better and retain more when using some form of "hands-on" exercises.

I am not too sure that our students will have enough of an attention span to engage in this LM the way it is designed. However, from a faculty perspective, the concept is great.

Make sure that required (student completion) time is factored into overall effort. You don't want beginners to do 20 hours of work for an assignment, when more experienced students can get by on less than 5.

This component outlined documents the key characteristics required to be successful. The one question I have remaining is how prevalent must the attention component be part of a concept (i.e lesson, module, unit, etc.)? The sense I have this is used to begin a lesson, but it may have to continued throughout the concept. Perhaps, more information around "attention" is necessary.

The goal or endgame needs to be stated within the course description and then reinforced through learning activities within the lab. Tying goals with outcomes and overall benefits will bring student and subject mater closer together. Ease of access may be a factor that keeps students present/attention when working the associated activities.

Relevance: *The laboratory model can be used to present computing content that is relevant to computing students.*

Yes, especially if the UI presents realistic circuits or networks or technical problems and if the "lab instrument dash boards" look like control panels of realistic devices.

No doubts: it is relevant to computing students.

The skills seem that they could be used in a range of settings.

My thinking is that this can be very relevant hands-on learning for students. Maybe if the design was included somehow as an in-class (versus an individual lab) participation project. I think students might engage more.

recommend having a minimal assignment for all to ensure students who need the work at least take a look at it. Students who are scared often skip help if offered. Students have to feel the lab will not only help them learn but also is related to completing their assignments.

Providing industry current best practices is a good methodology for keeping content relevant.

This component of ARCS is the most relevant and will be understood by most instructors. The one area for revision is the actual definition of "relevance" With the edits on page 4, relevance should also describe group needs in additional to individual needs. Given the variety in learning formats, it is important to describe this model in terms of the audience.

This is true for millennium and x/y gen students. Baby boomers may have some technical difficulty related to familiarity of current educational tools.

Confidence: *The laboratory can support the development of computing students' confidence.*

Small wins build competence and then confidence.

Yes, the students will feel a sense of accomplishment. They may be "lulled" into thinking that dealing with real world instruments are easy. So some progressive difficulty labs would be useful.

Absolutely: the Lab will support the development of computing students' confidence.

There are enough resources that students should be to be successful. Also they use resources that students can review them multiple times

Depends on how easily students feel they can access and work through the lab. But again, I think this LM concept is great.

In an ideal situation (difficult to achieve in practice) automatic, instant feedback from the simulation would help students gain confidence in their work. This is merely a comment on the side.

same as previous comment on relevance. Students need to understand how assignment is a benefit.

Instructor feedback has the ability to adapt to a number of formats. As stated in an earlier comment, credentialing systems can be incorporated to provide feedback. This demonstrates that the ARCS framework has a natural flexibility that can incorporated with the laboratory model.

I like the concept of smaller models that are focused and narrow. The path to completion is shorter so the reward of learning is easier to attain.

Satisfaction: *Computing students' satisfaction can be achieved with this laboratory.*

I am sure that this Lab will definitely support students' full satisfaction.

Yes, it should meet a wide range of student needs.

For students who manage to complete lab without too many challenges, I find that they think the lab LM types are very satisfactory in terms of their learning.

Provide examples for faculty to follow, methodology, for using tools in classroom. Have received feedback that students do not like going through exercises in class or watching the videos. Train faculty how to use toolwire and skillsoft in a live classroom setting. Would like to know 1-2 faculty success stories where lab has worked and students have bought in. Sharing best practices of what works in lab model will improve students' satisfaction.

From my perspective, I see the opportunity to formalize my existing course with this portion of the framework. My course contains components for additional learning and motivation to further learning by solving more challenging problems.

Building student confidence is a key component of laboratory work.

Short and clearly defined steps to an end goal I believe would be a overall approach. Focus on short lesson format where the goals are just a small stretch so there is a feeling of accomplishment. These courses can be hooked together to reach the objectives of a larger goal.

In addition to your comments above, what specific thoughts, questions, and/or recommendations do you have for improving instructors' laboratory content design skills, increasing access to relevant laboratory materials for a course you teach, and/or best practices to minimize the time and effort required to implement a web-based laboratory in a course you teach?

It would be helpful for instructors and students to have virtual reality or augmented reality videos on YouTube© that show someone doing the lab. Initially just having a lab developer make a Youtube© video that explains the goal of the lab and then presents the design aspects and the implementation steps of the lab would be needed.

Soonest implementation of this innovative Lab would bring true effectiveness of students' learning and faculty's teaching processes.

This model will allow instructors to teach current and relevant skills with out continually updating materials. Once there is cohort of instructors collaborating on the class, enhancements and continuous improvement will be the norm

Overall I feel this is an excellent "snapshot" of the web-based lab in computing courses. Well done!

I say keep up the good work in this area. In time, "student" challenges will be overcome with lab content.

Good to go.

I've used components of the lab model with mixed results in my classes. I find the resources easy to find/use, but need more guidance in the best practices to implement in the classroom successfully.

Adding exercises that are relevant and encouraging students to complete them timely will have a positive effect on the learning outcome. This also reinforces the use of the laboratory model as a valid learning mechanism.

1. An area for improvement is the use of assessment tools for grading to support emerging models. As an instructor, I feel limited in the ability to use established LMS tools for assessment. In an increasingly more holistic academic culture, assessment tools should match these emerging frameworks.

2. Video tutorials, especially for programming, could benefit from a central source. In computer programming, there are a number of free online tutorials available (i.e pvtuts.com). However, a curriculum site dedicated to computer science could be a catalyst. This would differ from a Khan Academy where the concepts for programming are taught from the ground up, rather than using visual tools that may place the emphasis on a tool, rather than a concept.

3. Platform-independent resources are paramount. Many examples are specific to the language or operating platform. An opportunity to emphasize that concepts do have computing limitations would be relevant in any tutorial. Again, this dependent on the course objectives, but the opportunity exists for this key improvement in online tutorials.

4. A curriculum sharing site, that can be mapped to standards (i.e. ACM, IEEE, etc), combining this proposed framework (and other frameworks) may provide a catalyst on the importance of computer education. As an instructor, being able to share resources and find lesson plans that are relevant to course objectives is a time consuming process. Have a resource that could be peer-evaluated and approved may help reduce the challenges with developing curriculum and learning tasks associated with a course. 5. From an academic honesty perspective, online resources present a wealth of supporting knowledge, but an opportunity for students to take advantage of systems. From a programming perspective, tools like turnitin.com for code would be helpful. Such a project exists (the MOSS Project at Stanford University), but having an easy-to-implement system will allow instructors to focus on developing meaningful lessons, rather than having to combat potential operational challenges.

5. The creation of online programming tools, that are integrated with LMS technologies and not necessarily open to crowd-sourcing, would allow for web-based simulations and labs. However, time and effort must be placed towards the development of such tools.

I am glad to see the learning objectives section expanded. Students should know what the end goal is for them in terms of learning.

The model is very doable and can to lead to overall student success.

Appendix Q

Consensus Comparison Table

	Round One	Round Two	Round Three
Participants	n=13	n=13	n=12
Adaptability	Yes = 100%	Mean = 4.23 Median = 4	Mean = 4.58 Median = 5
Practicality	Yes = 77%	Mean = 4.23 Median = 4	Mean = 4.45 Median = 5
Usability	Yes = 77%	Mean = 4.08 Median = 4	Mean = 4.36 Median = 4
Attention	Yes = 69%	Mean = 4 Median = 4	Mean = 4.58 Median = 5
Relevance	Yes = 69%	Mean = 4.31 Median = 4	Mean = 4.83 Median = 5
Confidence	Yes = 92%	Mean = 4.39 Median = 4	Mean = 4.64 Median = 5
Satisfaction	Yes = 85%	Mean = 4.31 Median = 4	Mean = 4.58 Median = 5
Overall	Yes = 81%	Mean = 4.22 Median = 4	Mean = 4.58 Median = 5

Appendix R

Final Laboratory Overview
(New and revised content is in italics)

Laboratory Overview

Hands-on experiential learning activities are an important component of computing disciplines. Laboratory environments provide learner access to real world equipment for completing experiments. Local campus facilities are commonly used to host laboratory classes. While campus facilities afford hands-on experience with real equipment high maintenance costs, restricted access, and limited flexibility diminish laboratory effectiveness. Web-based laboratory formats have emerged as low cost options, which allow open access and learner control.

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Objective	CBL (Skillsoft© Activities)	Simulation (You Tube©)	Laboratory Activity (Tool Wire©)
Practice Database Design Principles.	*Define Entities and Attributes for ERD Modeling* topic.	*Entity Relationship Diagram (ERD) Training Video* (Baldazzi, 2013).	Create a rough ERD using Visio 2010.
Create an ERD using MS Visio.	*Model Relationships in the ERD* topic.	*Working With Entity Relationship Diagrams (Telombardi, 2012)*	Complete your Visio ERD for Brocadero Online University from the previous lab exercise.
Create database tables using MS Access.	*The Physical Database Design Implementation* module.	*Working With Database Tables Parts 1, 2, and 3* (LearnMAccess, 2010).	Using your ERD create tables for a Brocadero Online University database in Access 2010.
Normalize MS Access database to 3rd normal form.	*Defining Normalization and its levels* module.	*Normalisation Demonstration* (McNichol, 2009).	Normalize the Brocadero Online University tables.

Table 1 Database Design Laboratory Overview

Web-based remote laboratories allow learners to experiment in an authentic computing environment using real computer hardware and software with significantly lower operating expenses than hands-on laboratories. Students manipulate experimental equipment remotely and laboratories can be shared among multiple learners without temporal or physical restrictions. Remote laboratories have been criticized for a lack of physical presence and functionality that is too complex for novice learners.

Web-based combined laboratories integrate multiple laboratory formats and learning resources. An advantage of combined laboratories is flexible access to a range of materials that allow students to review and rehearse experimental concepts prior to completing a laboratory assignment. In a combined laboratory format web-based simulation was shown to help novice learners prepare for more complex hands-on laboratories.

A laboratory course based on the combined laboratory model is organized into several units. Each unit covers one primary concept and addresses a single experiential learning objective. Computer Based Learning (CBL) modules, simulation learning, and laboratory activities are completed to fulfill the requirements of the unit objective.

For example, table 1 presents an overview of a web-based database design laboratory that was piloted in an introductory database concepts course. The laboratory supported students' practicing and learning of database design skills and best practices. Content for the course was divided into units that covered the concepts of entities and attributes, entity relationship diagrams, database tables, and normalization. The laboratory facilitated learning the concepts, practicing the design skills, and creating a simple relational database using a real-world relational database program.

The web-based combined laboratory model is composed of several components including learning objectives, computer based learning (CBL) modules, simulation activities, and laboratory exercises. Ideally, existing objectives and materials can be used with the model to design and implement a laboratory course. Off the shelf resources include commercially available training tools such as Skillsoft©, YouTube© videos, and web/computer tools to support skill based activities. Instructor developed objectives and materials are readily compatible with the laboratory model when off-the-shelf resources are not available.

Components

Objectives

Learning objectives guide laboratory course design. Typically laboratory activities are integrated into a computing course using or building on existing course objectives. The purpose of the laboratory is to support experiential learning or learning by doing and the instructor should insure one experiential learning objective per module. For example the previously described database design laboratory was created to support completion of existing experiential learning objectives such as "Create an ERD using MS Visio©", which guided students' in one step of the process of designing and developing a working relational database. When experiential learning objectives are not available the instructor will need to develop the objectives required to guide the desired skill development.

Computer Based Learning Modules
Computer Based Learning (CBL) allows self-paced review of the important concepts associated with each learning objective. For example the Skillsoft © CBL modules used in the first unit of the database design laboratory described the role of entities and attributes in preparing an entity relationship diagram (ERD) and included periodic learning assessments. CBL is designed primarily for novice learners. Completion of the CBL modules by all students is not a requirement of the model. Advanced students who are familiar with the concepts may elect not to complete the CBL modules. If the laboratory is led by the instructor a pretest may be used to determine who must complete the CBL modules. Available on the web, these activities are self-paced and learners can view, repeat, or skip each module as desired. Learners who understand the concepts provided by the CBL are ready to proceed to simulation.

Simulation Demonstration
Simulation provides a demonstration of the skill directed by the unit objective. In the first unit of the database design laboratory a YouTube© video was used to show learners how to develop entities and attributes from business rules. While novice learners find simulation particularly helpful, completion by all students is not a requirement of the model. Simulation activities are self-paced and learners can view, repeat, or skip each module as desired. Learners who understand the skill demonstrated by the simulation demonstration are ready to proceed to the laboratory activity.

Laboratory Activity
CBL and simulation prepare the novice learner to demonstrate the desired skill in a laboratory exercise. In the case of the first unit of the database design laboratory students developed entities and attributes from a business scenario provided by the instructor. Each laboratory exercise can be used to provide scaffolding and a summative evaluation of the students' achievement of the learning objective for the unit. Teamwork can be integrated into the laboratory activity to increase learner discussion and reflection. All of the units of the laboratory may be completed and repeated as needed.

Resources
This component can be challenging as organized validated content may not be readily available. The model can adapt to a wide variety of existing open source, commercial, or instructor produced materials. Resources are limited only by an instructor's imagination. Many institutions subscribe to commercial resources such as Skillsoft©, LabSim©, or Toolwire©, which are easily integrated into the Web based combined laboratory. Additionally, there are a significant number of open source tools available at education websites and YouTube©. Instructor produced videos or presentations are also appropriate for use with the model. The model is designed for implementation by instructors with varied teaching experience in a variety of learning formats.

Implementation

Laboratory implementation is intended to be flexible. Although the web-based laboratory model was envisioned as a stand-alone learning tool for remote use by students, it can be used in a classroom setting. An instructor's judgment is the best guide for appropriate laboratory implementation. To date the laboratory model has been piloted only in a local campus database concepts classroom under the guidance of the researcher. While the pilot studies confirmed the completeness and flow of components little is known about how the model will function in different courses and learning formats.

Motivation Strategies

Using the ARCS model framework the web-based combined laboratory model incorporates computer based learning, simulation, and remote hands on activities. Motivation and learning require *attention* be captured and maintained through a variety of materials that make the learning experience stimulating and interesting. The laboratory employs computer based learning, multimedia, and hands-on exercises to provide instructional variety to maintain attention. *Relevance* is gained by meeting individual needs in ways that are useful in the lives of the students. The topics presented in the laboratory are aligned closely with objectives students must achieve to succeed in the course. Learners gain *confidence* through completion of activities in which they control their own success. Confidence results from the presentation of theory and content in manageable units that allow students' control over the time and pace of learning. Ultimately, *satisfaction* comes from achieving a challenging computing education learning objective through completion of a laboratory assignment. If attention relevance and confidence are achieved students will be motivated to learn. Satisfaction is required to ensure a continuing desire to learn.

Attention

- Attention is required for motivation to occur
- Make obvious the benefits of successful completion of the laboratory
- Teaching and learning techniques should be changed frequently
- Use a variety of engaging materials, resources, and presentation modalities
- Incorporate scenarios such as what-if situations
- Adapt activities to a variety of mobile computing devices
- *Provide frequent feedback such as error output trapped during operations*
- *Use platform independent resources for ease of use and to avoid distratction*

Relevance

- Include activities that match students' learning goals
- *Hands-on activities are paramount*
- Align activities with course theory, *concepts*, and objectives
- Incorporate real world *interfaces*, scenarios, hardware, and software
- Integrate content that supports instructional goals
- Use vendor and user group resources

Confidence

- Design a series of short modules that can be completed successfully by students

- *Include several short experiences each week*
- *Use a clear step by step approach with complex topics*
- Provide clear objectives
- Frequent instructor feedback
- Give learners control of pace and access to activities
- Offer frequent opportunities for assessment that demonstrate success

Satisfaction

- Conduct a rigorous and objective assessment of the laboratory exercise component
- *Implement tools to enforce academic honesty*
- Provide opportunities to apply new skills
- Include as system for providing intrinsic and extrinsic rewards
- *Use micro-credentials to recognize learner progress*

References

Abdulwahed, M., & Nagy, Z. (2011). The TriLab, a novel ICT based triple access mode laboratory education model. *Computers & Education*, *56*(1), 262–274. doi:10.1016/j.compedu.2010.07.023

Accreditation Board for Engineering and Technology. (2010). *Criteria for accrediting computing programs*, (pp. i–8). Retrieved from http://www.abet.org/wp-content/uploads/2015/04/abet-cac-criteria-2011-2012.pdf

Bohlin, R., Milheim, W., & Viechnicki, K. (1993). The development of a model for the design of motivational adult instruction in higher education. *Journal of Educational Technology Systems*, *22*(1), 3-17.

Boston, W., & Ice, P. (2011). Assessing retention in online learning: An administrative perspective. *Online Journal of Distance Learning Administration*, *14*(2), 1–11.

Branch, R., & Kopcha, T. (2014). Instructional design models. In J. Spector, M. Merrill, J. Elen, & M. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (4th ed., pp. 77–86). New York, NY: Springer New York. doi:10.1007/978-1-4614-3185-5

Burd, S., Conway, C., & Seazzu, A. (2009). Virtual computing laboratories: A case study with comparisons to physical computing laboratories. *Journal of Information Technology Education: Innovations in Practice*, *8*, 55–78.

Cano, M. (2010). Using a remote emulated laboratory in a distributed information systems course. *2010 IEEE Frontiers in Education Conference (FIE)*, 1-6. doi:10.1109/FIE.2010.5673592

ChanLin, L. (2009). Applying motivational analysis in a web-based course. *Innovations in Education and Teaching International*, *46*(1), 91–103. doi:10.1080/14703290802646123

Chao, L. (2010). Development of computer lab with open source private cloud technology. *Journal of Technology Integration in the Classroom, 2*(3), 91–101.

Chen, S. (2010). The view of scientific inquiry conveyed by simulation-based virtual laboratories. *Computers & Education*, *55*(3), 1123–1130. doi:10.1016/j.compedu.2010.05.009

Choi, Y., Lim, S., & Oh, T. (2010). Feasibility of virtual security laboratory for three-tiered distance education. In *Proceedings of the 2010 ACM Conference on Information Technology in Education*, 53–57.

Clayton, M. (1997). Delphi: a technique to harness expert opinion for critical decision-making tasks in education. *Educational Psychology, 17*(4), 373–386. doi:10.1080/0144341970170401

Cook, D., Beckman, T., Thomas, K., & Thompson, W. (2009). Measuring motivational characteristics of courses: Applying Keller's instructional materials motivation survey to a web-based course. *Academic Medicine, 84*(11), 1505–1509.

Corter, J., Esche, S., Chassapis, C., Ma, J., & Nickerson, J. (2011). Process and learning outcomes from remotely-operated, simulated, and hands-on student laboratories. *Computers & Education, 57*(3), 2054–2067. doi:10.1016/j.compedu.2011.04.009

Cresswell, J. (2007). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches* (5th ed.). Thousand Oaks, CA: Sage Publications, Inc.

Dalkey, N., & Helmer, O. (1963). An experimental application of the Delphi method to the use of experts. *Management science*, *9*(3), 458-467.

Driscoll, M. (2005). *Psychology of learning and instruction* (3rd ed.). Boston, MA: Pearson Education, Inc.

Fernandez, R. (2014). *A cognitive apprenticeship approach for teaching abstract and complex skills in an online learning environment* (Doctoral dissertation). Retrieved from http://www.nova.edu/library/main/

Field, J., Merrill, B., & West, L. (2012). Life history approaches to access and retention of nontraditional students in higher education: A cross-european approach. *European Journal for Research on the Education and Learning of Adults*, *3*(1), 77–89. doi:10.3384/rela.2000-7426.rela0062

Gibbons, A., Boling, E., & Smith, K. (2014). Instructional design models. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology*. (4th ed., pp. 607–615). New York, New York, USA: Springer. doi:10.1007/978-1-4614-3185-5

Green, M. (2012). Designing a web-based laboratory class to engage 21st century learners. *Journal of Applied Learning Technology*, *2*(2), 24–28.

Hasson, F., & Keeney, S. (2011). Enhancing rigour in the delphi technique research. *Technological Forecasting and Social Change*, *78*(9), 1695–1704. doi:10.1016/j.techfore.2011.04.005

Hsu, C., & Sandford, B. (2007). The delphi technique : Making sense of consensus. *Practical Assessment, Research & Evaluation*, *12*(10).

Jolliffe, A., Ritter, J., & Stevens, D. (2012). *The online learning handbook: Developing and using web-based learning* (Online.). New York, NY: Routledge.

Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS model approach* [Kindle Edition]. doi:10.1007/978-1-4419-1250-3

Kim, K., and Frick, T. (2011). Changes in student motivation during online learning. *Journal of Educational Computing Research*, *44*(1), 1-23. doi: 10.2190/EC.44.1.a

Konak, A., Clark, T., & Nasereddin, M. (2014). Using Kolb's experiential learning cycle to improve student learning in virtual computer laboratories. *Computers & Education*, *72*, 11–22. doi:10.1016/j.compedu.2013.10.013

Lahoud, H., & Krichen, J. (2010). Networking labs in the online environment: Indicators for success. *Journal of Technology Studies*, *36*(2), 31–40.

Linstone, H., & Turoff, M. (1975). *The Delphi Method: Techniques and Applications*. Reading, MA: Addison-Wesley. Retrieved from https://www.ncjrs.gov/App/Publications/abstract.aspx?ID=256068

Ma, J., & Nickerson, J. (2006). Hands-on, simulated, and remote laboratories: A comparative literature review. *ACM Computing Surveys*, *38*(3), 1-24. doi:10.1145/1132960.1132961

Newman, D., & Clure, G. (2012). Moving towards an online user typology: The importance of learner characteristics for non-traditional users. *Society for Information Technology and Teacher Education*, 706–711.

Okoli, C., & Pawlowski, S. (2004). The delphi method as a research tool : An example, design considerations and applications. *Information and Management*, *42*(1), 15–29.

Rao, K. (2012). Universal design for online courses: Addressing the needs of non-traditional learners. *IEEE 2012 International Conference on Technology Enhanced Education*, 1–8. doi:10.1109/ICTEE.2012.6208664

Richey, R. (2005). Validating instructional design and development models. In J. Spector, C. Ohrazda, A. Van Schaack, & D. Wiley (Eds.), *Innovations in Instructional Technology: Essays in Honor of M. David Merrill* (pp. 171–186). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Richey, R., & Klein, J. (2007). *Design and Development Research*. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Richey, R., & Klein, J. (2014). Design and Development Research. In J. Spector, M. Merrill, J. Elen, & J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology*. (pp. 141–150). New York, NY: Springer New York. doi:10.1007/978-1-4614-3185-5

Rogers, Y., Sharp, H., & Preece, J. (2011). *Interaction Design: Beyond Human Computer Interaction* (3rd ed.). Chichester, West Sussex: Wiley.

Rowan-Kenyon, H., Swan, A., Deutsch, N., & Gansneder, B. (2010). Academic success for working adult students. In Perna, L. (Ed.), *Understanding the working college student: New research and its implications for policy and practice*, 93-112. Sterling, VA: Stylus Publishing.

Rutten, N., Van Joolingen, W., & Van der Veen, J. (2012). The learning effects of computer simulations in science education. *Computers & Education, 58*(1), 136–153. doi:10.1016/j.compedu.2011.07.017

Sarkar, N., & Petrova, K. (2013). Design and evaluation of a web-based tool for teaching computer network design to undergraduates. In Karacapalidis, N., Raisinghani, M., & Ng, E. (Eds.), *Web-Based and Blended Educational Tools and Innovations*, (pp. 214-231). Hershey, PA: IGI Global.

Sauro, J., & Dumas, J. (2009). Comparison of three one-question, post-task usability questionnaires. *Proceedings of the 2009 ACM Conference on Human Factors in Computing Systems*, 1599–1608. doi:10.1145/1518701.1518946

Shneiderman, B., & Plaisant, C. (2010). *Designing the User Interface: Strategies for Effective Human - Computer Interaction* (5th ed., p. 576). Boston, MA: Addison-Wesley.

Terrell, S. (2012). *Statistics Translated: A Step-by-Step Guide to Analyzing and Interpreting Data* (pp. 1–409). New York, NY: Guilford Press.

Uludag, S., Guler, E., Karakus, M., & Turner, S. W. (2012). An affordable virtual laboratory to complement a variety of computing classes. *Journal of Computing Sciences in Colleges*, *27*(5), 158–166.

U.S. Department of Education, National Center for Education Statistics, Institute of Education Sciences. (2011). *Digest of Education Statistics: 2011*. Retrieved from http://nces.ed.gov/programs/digest/d11/

Wedemeyer, C. (1981). *Learning at the Back Door: Reflection on Non-Traditional Learning in the Lifespan*. Madison, WI: University of Wisconsin Press.

Wolf, T. (2010). Assessing student learning in a virtual laboratory environment. *IEEE Transactions on Education*, *53*(2), 216–222.

Xu, L., Huang, D., & Tsai, W. (2012). V-lab: a cloud-based virtual laboratory platform for hands-on networking courses. *Proceedings of the 2012 ACM Conference on Innovation and Technology in Computer Science Education*, 256–261.