

Benefits and Challenges Associated with Using Virtual Laboratories and  
Solutions to Overcome Them

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# Benefits and Challenges Associated with Using Virtual Laboratories and Solutions to Overcome Them

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## **Abstract**

This study investigated the benefits and challenges associated with the use of virtual labs to teach students, as well as solutions to overcome the challenges. This study was because of the need to develop and implement virtual labs in Zambian institutions of learning. There are plans in Zambia to use virtual labs to supplement the existing laboratory infrastructure and their application would be in a blended type of setting.

The study comprised the use of interviews of ten career and technical education (CTE) teachers and five CTE administrators who were from various local school systems and one community college in the Commonwealth of Virginia. The researcher conducted the interviews, analyzed the data, and determined conclusions.

The CTE administrators and teachers all agreed that the benefits of virtual labs included flexibility, hands-on learning, and convenience. With regard to challenges, CTE administrators indicated the following: inadequate teacher preparation for virtual teaching; constant technological changes, which meant more training for them; software problems; and teachers' resistance to the changes in their curricula. Teachers, on the other hand, had the following challenges: inadequate communication between them and the technology centers in the schools, frequent failure of laboratory equipment and software, incompetent students allowed to study virtually, and inadequate training to teach in a virtual environment.

CTE administrators identified three solutions to the challenges which they had faced. In order to ensure that their virtual programs were running smoothly, they felt that adequate funding needed to be obtained and kept in the budget for training new and older teachers in the use of

new teaching software. They identified various venues for training teachers, including attendance at conferences, technological expositions, and bringing in software vendors to train the teachers on site. The administrators also thought that providing adequate and prompt technical support when teachers had technical problems could help overcome the identified challenges. On the other hand, CTE teachers thought that collaborating with other teachers who were facing similar problems would be an excellent way to overcome challenges. They also indicated that initial training and continual training to update their skills would help them overcome problems.

## **Dedication**

I would like to dedicate this doctoral dissertation to the memory of my late father, Mr. Theodore Daniel Ngoyi and to the living love of my mother, Musawu Bernadette Ngoyi. There is no doubt in my mind that without these two people's love for me and their continued support and counsel I could not have completed this process. This dissertation is also dedicated to the love of my life, Hellen Muke-Ngoyi who has been with me from the beginning until the end which is nigh. I would also like to dedicate this dissertation to my children Daniel, Mapalo, Clement, and Imani. Your being in my life is something that I cannot describe in words. I just know what it feels like whenever I am reminded that I have you.

To God and Christ I am also grateful for the encouragement found in Philippians 4:13:

“I have done all these things through Christ who has been strengthening me”!

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## **Acronyms**

CTE	Career and Technical Education
ICT	Information Communication Technology
NASA	National Aeronautics and Space Administration
TEVET	Technical Education, Vocational, and Entrepreneurship Training
UNDP	United Nations Development Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
VLE	Virtual Learning Environment

## **Chapter 1: Introduction**

New technological challenges and opportunities have thrust educators into being confronted with rapidly changing educational, social, and economic scenarios. Educators in engineering and technical training, more than ever before, are faced with a demand to develop and integrate theoretical and practical learning sequences that will allow them to fulfill the need for highly qualified engineers and technologists (Bruns & Erbe, 2004 ). To ensure the integration of theoretical and practical learning, educators have, for many years, utilized laboratory experiences. These experiences reinforce the learning of theoretical concepts and provide the transition from theoretical to practical understanding. Woodfield et al. (2004) suggested that the main purposes of instructional laboratory sessions included the teaching of laboratory techniques and analytical thinking skills, as well as making a strong correlation of the theory learned with laboratory practice. They also stressed that developing laboratory skills requires students to undertake authentic experimental tasks within the lab setting.

Today, because the internet is an almost universally available communications infrastructure for learning, virtual instruction has become a popular alternative method of course delivery to assist schools, colleges, and universities in expanding access to instruction at both national and international levels (Shelton & Saltsman, 2004). Not only does this type of instruction allow educational institutions to expand access to their courses, it also provides individuals an opportunity to improve their financial and societal well-being while raising their educational attainment at the same time. Although educators are beginning to gain more experience with using virtual course delivery tools, the use of virtual labs is relatively new and the true costs of high quality virtual instruction and potential economies of scale are unclear (Tucker, 2007). This lack of knowledge concerning the learning outcomes for students from



virtual labs has created pressure on educators to prove their effectiveness. The United States federal and state governments and various accrediting agencies, for example, are beginning to require proof of effectiveness (Carneval, 2001). In addition to using virtual labs in distance learning, many educational institutions are using them on their campuses and are being faced with the same scrutiny as those who use them in distance education. As the use of virtual labs continue to become more prevalent, institutions must demonstrate how well they fulfill their purpose and must engage in an ongoing quest to provide documentation of the quality and effectiveness of their programs.

### **Statement of the Problem**

Because of the severe inadequacies of training laboratories in Zambian schools and the fact that there is not enough laboratory space to meet the demand for laboratory experiences, there is a need to develop and implement virtual labs.

### **Purpose of the Study**

The main purpose of this study was the identification of benefits and challenges associated with using virtual laboratories, the solutions for overcoming the challenges, and factors to consider when planning the development and implementation of virtual labs in developing countries like Zambia or in communities that have limited financial resources.

### **Background**

In Zambia, formal education is mainly based on a three-tier system, starting with primary education from grades 1 to 7, and then followed by secondary education from grades 8 to 12. The next level relates to tertiary education, which includes college and university education. The primary and secondary cycles last for 7 and 5 years respectively. Alternatively, the duration of tertiary education varies widely depending on the education program load and certification

requirements. These three levels constitute the formal education system in Zambia. (Central Statistics Office, Zambia, n.d.). Over 3,000,000 pupils enter grade 1; by grade 5, half of the pupils drop out. This is due to lack of motivation, long distances to schools, and available space. The progression rates from grade 9 to 10 reveal that over 20% of pupils are lost due to finance and lack of space in secondary schools. In addition, the selective examination of pupils in grades 7, 9 and 12 inhibits universal progression of pupils from one level to another, and those who fail are never encouraged to repeat their grades (Central Statistics Office, Zambia, n.d.).

Because of the large number of dropouts during the 12 years of formal education, the final number to graduate from high school is a little over 50,000 per year (United Nations Development Program [UNDP], 2011). Out of the 50,000, the vocational education and training system is only able to absorb 14,000 annually (UNDP, 2011). According to the UNDP (2011), less than 13 % of the population has access to entrepreneurial and vocational training services, whereas the average for middle-income economies is between 20 and 30%. The current potential demand for tertiary education, estimated at 1.63 million youths by the Ministry of Science, Technology and Vocational Training, is very high, and far from being met. Universities have a total annual intake of about 5,000 students, with a quarter of them being students who are already working in industry. There are two reasons for a mismatch between the numbers applying and the numbers admitted. The first reason is that applicants do not all satisfy an institution's admission criteria; the second is that the institutions do not have the capacity to admit all qualified applicants (Mwansa et al., 2004). Both reasons apply, but the major reason is that admissions capacity in institutions of higher education falls short of the demand due to the lack of adequate resources. There are very few college and university places available as compared to the number of eligible applicants (UNDP, 2011). This is also true with regards to

the progression of students from grades 1 through 12. Students who do not pass a given grade are not encouraged to repeat that grade because of the lack of classroom space throughout the country. However, to help alleviate the enrollment problem, two strategies are now being explored in Zambia. First, the education system throughout the country has been liberalized to allow more participation of all stakeholders in the financing and administration of education. This participation will create more classrooms. This new arrangement has worked to some degree for primary and secondary education. However, there are very few people interested in investing resources into higher education, even though it has been reported in some sections of the media in Zambia that the Zambian government intends to open 3 new universities in the next 5 years (Chikwanda, 2011, November 11). Second, the use of virtual learning is being strongly considered, including the use of virtual labs. Both of these strategies, new private schools and the use of virtual learning, can yield positive effects to help alleviate the educational supply and demand problems in the country (Ministry of Education, Zambia, 2007).

As part of the higher education system in Zambia, Technical, Education, Vocational and Entrepreneurship Training (TEVET) technical colleges provide a variety of training programs, all of which require the use of a laboratory. According to Miyagawa and Luczynska (2005), these laboratory settings are inadequate and in short supply. Since virtual labs are being considered as one of the measures to combat the inadequacies and short supply, it would be very helpful to identify the benefits and challenges that exist when developing and implementing these labs and solutions to overcome the challenges. This research study sought to investigate these benefits, challenges, and solutions. At the time of doing this research, there were no known institutions in Zambia where virtual labs were being used as a mode of instruction. Therefore, the identification of benefits, problems and solutions related to using virtual labs as an

instructional tool was researched in selected schools where virtual labs were being used, in this case, selected schools in Virginia, USA. Although the research was conducted in a different setting, it was felt that this investigation could yield results that would still be useful in Zambia. As with all qualitative studies, readers of the study's results can extrapolate information that they feel can be applied to their own situation.

### **Importance of the Study**

According to Barbour and Reeves, (2009), proponents of virtual schooling have concluded that there are a number of benefits associated with virtual schooling. These benefits can be summarized into five main areas: (a) expanding educational access, (b) providing high-quality learning opportunities, (c) improving student outcomes and skills, (d) allowing for educational choice and, (e) achieving administrative efficiency. They continue to say, however, that whether these benefits are actually realized through virtual schooling remains in doubt in the minds of some critics, and the research to support these assumptions is limited at best. The results of this study were intended to be used as a source of reference for developers and implementers of virtual labs in Zambia. It was felt that by gaining knowledge of the benefits, challenges and solutions associated with using virtual labs, as experienced by veteran instructors who have used this type of lab, would assist in preventing selected challenges from happening. Furthermore, if a similar given challenge is experienced in Zambia, an identified solution could possibly be used to overcome it.

### **Research Questions**

The study was conducted to answer the following research questions:

1. What are the benefits associated with using virtual labs?
2. What are the challenges associated with developing and implementing a virtual lab?

3. What are the challenges associated with using virtual labs to teach on a day-to-day basis?
4. What solutions can be used to overcome the challenges associated with developing and implementing a virtual lab?
5. What solutions can be used to overcome the challenges associated with using virtual labs to teach on a day-to-day basis?
6. What factors should be considered when planning the development and implementation of virtual labs?

### **Theoretical Framework**

The desire to implement virtual labs is born out of a combination of the theory of social constructivist learning and experiential learning. According to constructivism, human beings develop knowledge by way of engaging in a situated task (endogenous constructivism) and social negotiation (dialectical constructivism). Constructivists suggest the use of authentic tasks and tools can be used to avoid misconceptions due to otherwise inappropriate simplifications (Duffy & Jonassen, 1992). Complexity challenges students' mental models in a demanding and motivating way. Students develop self-confidence and perceive progress in building collective knowledge (Koschmann, 1995). We can conclude that virtual labs are adequate tools for the support of constructivist learning if they:

1. Carry authenticity;
2. Make research tools easy to share complexity;
3. Visualize complex data to promote insight collaboration and;
4. Support computer-mediated communication.

The theory of experiential learning stems from the constructivist school of thought. John Dewey first wrote about the benefits of experiential education in 1938, explaining that there was

an intimate and necessary relation between the processes of actual experience and education (Dewey, 1938/1997). Experiential learning theory propagates learning through experience and by experience. According to this theory, learning is understood as an iterative process whereby knowledge is created through the transformation of experiences (Kolb, 1984). A more in-depth discussion of the theoretical framework for this study is provided in chapter two, the review of literature.

### **Overview of Research Design**

A qualitative research design was utilized to conduct this research. It included separate interviews with Career and Technical Education (CTE) teachers and administrators who have experience with using virtual labs. The researcher visited selected schools and colleges in the City of Newport News, Loudoun, Giles, Roanoke, Pulaski, and Montgomery counties in Virginia to meet and interview the research participants. Once data were collected from interviews, a synthesis of information gathered was completed and results were analyzed and reported as presented in the findings, conclusions, discussion, and recommendations sections of this document.

Other than the literature review, the research design in this study comprised:

1. Identifying research participants and their locations;
2. Conducting a pilot study to determine any deficiencies in the research interview instrument protocol and to determine the reliability and validity of the questions used on the instrument;
3. Getting an approval of the IRB;
4. Making contact with interview participants;

5. Making trips to interview sites where the researcher made face-to-face contact with the interviewees and;

6. Analyzing the data and determining the findings and conclusions of the study

A more detailed description of the research design is presented in Chapter 3 of this report.

### **Assumptions**

This study was conducted based on the following assumptions:

1. Many of the fundamental aspects of utilizing virtual labs are common regardless of the setting, in this case, Zambia and USA.
2. Results of the study will include data that readers in Zambia will be able to extrapolate when they think it applies to their own situations.
3. There will be additional challenges in Zambia concerning the use of virtual labs that will also need to be identified within the country itself.
4. The information collected from this study with regards to virtual labs will have both educational and financial benefits to serve the people of Zambia.

### **Delimitations**

1. The study was delimited to selected schools and colleges located in Virginia.
2. The study was delimited to select Career and Technical Education (CTE) program areas as recommended by local CTE administrators.

### **Limitations**

The limitations of this study included:

1. Number of participants available to participate in the study.
2. Identification of institutions willing to share their experiences with virtual labs without a biased stance.

## **Definitions of Terms**

**Infrastructure:** The term “infrastructure” in this context does not necessarily relate to computers, but rather people, space, communicating hardware and software (Mason, McLean, & Wilson, 2004). The elements of a virtual lab infrastructure include: people working in it, the computers, the building in which the labs are housed, the network connections and the hardware and software which make the system run smoothly to allow students to conduct their labs.

**Online learning:** Online learning refers to: web-based training; e-learning; distributed learning; Internet-based learning; web-based instruction; cyber learning; virtual learning, or net-based learning (Urdan & Weggen, 2000, as cited in Keengwe & Kidd, 2010). It consists of a wide range of computer technology applications and learning processes including among which are: computer-based learning; web-based learning; virtual classrooms; and digital collaborations (Keengwe & Kidd, 2010; Paulsen, 2002).

**Onsite physical laboratory:** A building or room equipped for conducting scientific research or for teaching practical science where students can do their experiments in real time.

**Virtual instruction:** Virtual instruction is when a course is taught either solely online or when components of face-to-face instruction are taught online such as with Scholar and other course management systems. Virtual instruction includes digitally transmitting class materials to student.

**Virtual laboratory:** A virtual laboratory is an interactive environment for creating and conducting simulated experiments that encompass data files, the tools that make it operate. In general terms, a virtual laboratory is a computer-based environment where



students work with an experimental apparatus or other activities through the use of a computer medium.

Virtual Learning Environment, VLE: A VLE is a computer-based package designed to help teachers create online courses, together with facilities for teacher-learner communication and peer-to-peer communication. It allows learners to perceive the environment, assess situations and performance, perform actions and proceed through experiences and lessons that will allow them to perform better with more experience on repetition on the same task in similar circumstances. This definition of a virtual learning environment emphasizes the importance of learning (Pimentel, 1999)

Virtual school: Virtual school refers to an institution that is not "brick and mortar" bound. All student services and courses are conducted through Internet technology. The virtual school differs from the traditional school through the physical medium that links administrators, teachers, and students (Clark, 2001).

### **Summary**

In this chapter, the researcher: (a) introduced the purpose, (b) provided a background of the problem, (c) provided the statement of the problem, (d) presented the study's research questions, (e) introduced the research methodology, (f) provided the assumptions, delimitations, and limitations, and (g) defined appropriate terminology. The remaining chapters of the dissertation will contain: (a) a review the related literature, (b) a description of the research methodology, (c) presentation of the findings of the research, and (d) conclusions and recommendations.

## **Chapter 2. Literature Review**

This chapter has seven main sections: (a) It begins by with an overview of literature concerning the theory of constructivism, (b) followed by experiential learning, (c) a brief history of virtual realities and their applications, (d) current trends in e-learning, (e) the benefits of virtual labs, (f) the challenges associated with virtual learning, and (g) the literature review of interviewing as a tool for qualitative research concludes the chapter.

### **Constructivism**

Constructivism refers to the ability of an individual to construct his or her own knowledge based on one's beliefs and mental structures used to interpret individual constructs (Phillips, 2000; Solvie & Kloek, 2007). Jonassen (1991) stated that, "The mind is instrumental and essential in interpreting events, objects, and perspectives on the base that is personal and individualistic" (p. 29). The main idea of constructivism is that learning is an activity where individuals have the choice concerning whether or not to take up the information, even though the understanding of concepts should come from the learner's desire to learn. According to Woolfolk (1993), a constructivist environment was a social environment in which students' minds acted as medium of processing information to determine whether learning would occur. Modern learners use of information communication technologies has enhanced their understanding of class materials since they have been creating knowledge by making sense of what they have doing (Taylor & Hsueh, 2005). In constructivist learning, students are encouraged to gauge on how a given activity will help them learn by asking themselves and their strategies, hence becoming expert learners.

### **The Constructivist Learner**

A constructivist learner is one who is self-motivated and innovative and is the main focus of attention in constructivism. The learner enters the learning environment to create new

knowledge that is based on previous experience. Other than being just an individual, there is also collaboration among learners in a constructivist environment which ensures that there is no loneliness and enhances a sense of community in which learners and teachers participate in the acquisition of new knowledge (Jonassen, 1991). The responsibility for learning in a constructivist classroom rests on the learner (Wang, 2011). The instructor in a classroom attends to the students in their course while at the same time bearing in mind that learners have experiences which have shaped their knowledge and thought over time. There are several factors ranging from classroom and social conditions to culture which are responsible for learning (Cope & Kalantzis, 2000). Also, it is important to ensure that learners are independent of the teacher to a certain extent (Vansteenkiste, Simons, Lens, Deci & Sheldon, 2004).

### **The Role of the Teacher**

The role of a teacher in a constructivist classroom is merely to act as a facilitator and ensure that students are active in the learning process (Copley, 1992). Similarly, Omrod (1995) stated that teachers were capable of fostering student growth by giving them tasks that they could do based on each student's zone of proximal development. According to Brooks and Brooks (1993) a constructivist teacher is someone who is capable of letting students take initiative to learn by providing them with learning materials and then inquiring whether they have understood the concepts. Dewey (1910) explained the role of a teacher in a classroom as follows:

Teachers are the agents through which knowledge and skills are communicated and rules of conduct enforced...[teachers] must...have that sympathetic understanding of what is actually going on in the minds of those who are learning...any experience...that has the effect of arresting or distorting the growth of further experience [is miseducative]...every experience enacted and undergone modifies whether we see it or not, the quality of

subsequent experiences...The most important attitude that can be formed is that of desire to go on learning. (p. 3-4).

### **Constructivism and Technology**

The two main important features of constructivism are assimilation and accommodation. It is due to assimilation that a learner accepts to take in new ideas and put them into the existing ones to create new points of views and choose what is important and eventually get their views changed. Then the incorporation of the new ideas is completed when accommodation takes place. The same principles of constructivism are applicable to technology.

Technology plays a significant role in enhancing constructivism because technology and constructivism are used together to foster learners' understanding of lesson materials. Due to the use of technologies, there has been renewed attention focused on constructivism lately due to its ability to empower students with easy access to relevant information which fosters their learning (Mann, 1994). In this vain, technology is important in education because it will bring about changes in teaching and teachers will have no choice but use a constructivist approach to teach (LeBaron & Bragg, 1994).

### **Technology as Cognitive Tools**

The cognitive constructivist view of learning contends that an active and reflexive learner constructs personal knowledge through discovery and exploration in a responsive learning environment. Because the main argument of constructivism is learning by tools and signs (Nanjappa & Grant, 2003), with modern technologies, a constructivist learning environment can be transformed to embrace the technology and respond to the learning needs of a particular culture. As Duffy & Cunningham (1996) suggested that:

“Culture creates the tool, but the tool changes the culture. Participants in the culture appropriate these tools from their culture to meet their goals, thereby transforming their participation in the culture” (p. 180).

The personal computer serves as an example of a learning medium endowed with the attributes of a tool and a sign since it creates an exciting learning environment (Jonassen & Reeves, 1996). Having the focus on the learner as the most important player in the learning environment, using technology supports new understandings and discoveries which eventually go to support cognitive and metacognitive processes (Nanjappa & Grant, 2003). Duffy and Cunningham (1996) when making a case for the place of technology in the learning environment stated that:

....Technology is seen as an integral part of the cognitive activity. This view of distributed cognition significantly impacts how we think of the role of technology in education and training, the focus is not on the individual in isolation and what he or she knows, but on the activity in the environment. It is the activity – focused and contextualized- that is central. The process of construction is directed towards creating a world that makes sense to us, that is adequate for our everyday functioning (pp. 187-188).

Therefore the learner should be in a continued state of learning by using the available learning opportunities in order to catch up with technological changes (Lajoie, 2000). The traditional view of instructional technologies as drivers of academic knowledge is replaced by the learners’ active role in the constructivist classroom (Nanjapa & Grant, 2003). Learners also become the designers of their own knowledge by way of gathering data and relaying it to others (Jonassen, & Reeves, 1996). In a constructivist environment that is supported by technologies,

learners discover new data by way of using the available search engines and then transforming them into easily readable materials (Jonassen, Carr, & Lajoie, 2000).

## **Experiential Learning**

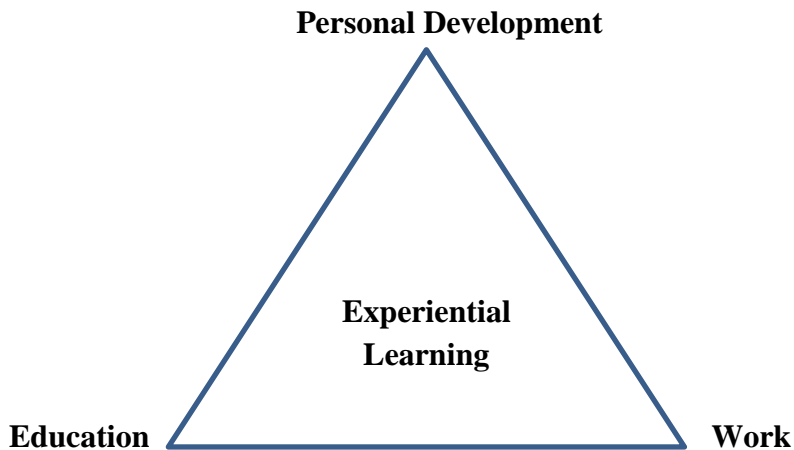
### **Contribution of John Dewey**

When discussing experiential learning, it would be important to consider one of the pioneers who articulated the philosophy of experiential learning, John Dewey. Dewey wrote about the benefits of experiential education by explaining that experience and education were intimately related (Dewey, 1938/1997). He also contended that the experiential component of education made it progressive and that if focus was only put on content, learning would be hindered because the opportunity for students to develop their own views while having interactions with lesson content would be limited. Dewey also suggested that each individual's experience was personal and related to past experiences and learning in an experiential classroom was a mimic of society in which members had different points of view about a subject. Dewey also expressed the need to make education progressive by way of creating a strong philosophy with emphasis on experience, productivity, and creativity which went on to make learning experiences stronger education (Dewey, 1938/1997).

Dewey's works were mainly a reflection of the progressive education movement in the United States of America in the first half of the twentieth century (Itin, 1999). Having brought in the place of experience in education, he was concerned with creating a relationship between education and reflection. Dewey considered knowledge to be insufficient if it did not show what it was capable of doing. As being a part of the progressive movement, he was more concerned with the place and meaning of subject-matter and the experience it brought with it. His view of education was that both the learner and the teacher were partners who were taking part in a

meaningful experience (Dewey, 1938). Dewey viewed the education process to be one which involved both teacher and learner engaged in a meaningful experience.

When stressing the importance of personal development, education, and work to experiential learning (Kolb, 1984), Dewey placed equal importance to the roles each of the three components played in experiential learning as depicted in figure 1.



*Figure 1.* Experiential Learning as the Process that Links Education, Work, and Personal Development. Adapted from *Experiential learning: Experience as the source of learning and development* (p. 4), by D.A. Kolb, 1984, New Hersey: Prentice Hall. Copyright 1984 by PTR Prentice Hall.

In Dewey's opinion, education was the tool for making the learner a full participant in the democratic process because he wanted educators to understand the nature of experience their learners came with and then initiate the education process (Kraft, 1986). Two most important aspects of experiential learning are continuity and interaction. Continuity means that every experience a person has, influences the future of that person and how it influenced a person's behavior in certain situations was the interaction itself. Therefore, a person's present experience is a function of the interaction between his or her past experiences and the present situation (Dewey, 1938). Dewey further wrote that once educators have a theory of experience, they could then organize their lessons to account for experiences and create an environment where students will open up to future growth experiences. Dewey also examined his theory of

experience in relation to everyday educational problems, such as classroom behavior management and discipline demonstrated that continuity and interaction can be useful guides to help solving such issues (Dewey, 1938/1997).

### **Kolb's Experiential Learning Theory**

Kolb's theory of experiential learning built upon the earlier works of John Dewey and others. It is based on the tenets of constructivism and says that learning is a continuous process which is formed by the changes in individuals' experiences - the basic idea is that it focuses on experience as an agent of learning (Kolb,1984). Kolb proposed a four-stage model, as illustrated in figure 2, to explain his theory. His theory says that the first thing that initiates learning is having a concrete experience and then a reflection which is assimilated into a theory before new ideas are tested in different situations.

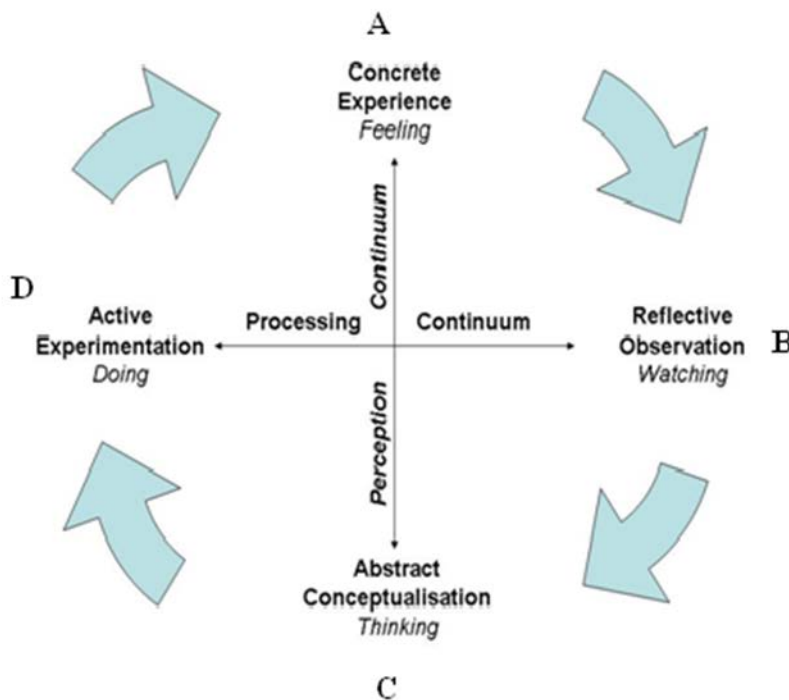


Figure 2. Kolb's Experiential Learning Cycle. Adapted from *Experiential learning: Experience as the source of learning and development* (p. 42), by D.A. Kolb, 1984, New Hersey: Prentice Hall. Copyright 1984 by PTR Prentice Hall.



**The learning cycle.** Kolb's learning cycle is such that it requires four processes to be present for any form of learning to be deemed complete. This part of Kolb's model is more useful because instead of trying to identify a learning style, he provides a model learning program. He called this Experiential Learning since experience is the source of learning and development (Kolb, 1984). Each part of the cycle indicates a stage in the learning process, namely:

1. Concrete experience (feeling): Concrete experience (CE), the first stage in the cycle, represents an active experience the learner may have in a specific class session or laboratory experiment. Step A represents learning from specific experiences which include being sensitive to other people's feelings;
2. Reflective observation (watching): CE is followed by the reflective observation (RO) stage in which the learner takes a look back at that particular experience and asks many questions about the experience before making a judgment. At Step B, the learner step back from the experience, observes it, and reflects on it. This might involve noticing similarities or differences, patterns, or results of certain actions;
3. Abstract conceptualization (thinking): Step C: Based upon his or her observations, RO is then followed by abstract conceptualization (AC) in which the learner attempts to conceptualize what has been observed into a theory about what was observed.
4. Active experimentation (doing): Step D, the learner then goes on to apply this principle or generalization to see if it holds true. (AE) is when the learner plans how to test the model he or she has conceptualized.

Step D leads to another concrete experience and the process goes on and on to create more new learning. The learner again makes new observations and reflections and, based on

them, reformulates the principle and again applies it. Kolb's model might be looked at as a cyclic process since the circle repeats itself, but each time on a more refined or sophisticated level due to the additional knowledge gained from the previous circle. Depending upon the situation or environment, the learners may enter the learning cycle at any point and will best learn the new task only if they complete four stages of the cycle. Kolb viewed the learning process as a context of people moving between the modes of concrete experience and abstract conceptualization, and reflective observation and active experimentation. Therefore, the effectiveness of learning depends on the ability to balance these modes, which Kolb saw as opposite activities that best promote learning (Kolb, 1999).

**Kolb's categories of learners.** Kolb's learning theory also gives an outline of categories under which individuals learn. These categories are assimilators, convergers, accommodators, and divergers.

*Assimilators.* These are who learn better when presented with sound logical theories to consider. The special characteristic that assimilators possess is their ability to logically arrange their information into tangible abstracts. They would rather be immersed in their reading activities as opposed to interaction with other people because they need time to think through what they have learnt.

*Convergers.* These are people who learn better when provided with practical applications of concepts and theories. Convergers are unique because their core duty is to find the practical applications of the theories and use the applications to answer questions or solve problems. They are mainly the people who are technologically savvy and tend to have a preference for simulations and hard sciences.

***Accommodators.*** These are individuals who learn better with hands-on activities. Accommodators are individuals who would rather decide based on their instincts instead of logical reasoning because they rely on others for solutions without using their own abilities. Careers where accommodators find are prevalent include places where they would rather work with other people and perform field functions like marketing.

***Divergers.*** These are people who learn better when allowed to observe and gather important data. The diverging stage usually involves people who are interested in other people's cultures, like group work and do better when they are tasked with generating ideas in activities such as brainstorming sessions because of their ability to view concepts from many perspectives.

Kolb proposed six main characteristics of experiential learning, namely:

1. Learning should be best conceived as a process, not in terms of outcomes;
2. Learning is a continuous process grounded in a learner's own experience;
3. Learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world;
4. Learning should be taken as a holistic process of adaptation to the world;
5. Learning involves transactions between the learner and the environment in which the learning is taking place; and
6. Learning is a process of creating knowledge resulting from the transaction between social knowledge and personal knowledge.

### **A Brief History of Virtual Realities**

The first viable example of a multisensory simulator, Sensorama, was demonstrated in 1962 by Morton Heilig (Scheinerman, 2009). Although this was not an interactive environment,

the system allowed users to sit in front of a screen and choose to watch pre-recorded rides of bikes and motorbikes through Brooklyn, New York while experiencing the noises and other features which were a virtual representation of that part of the city (Gutierrez, Vexo, & Thalmann, 2008). Ivan Sutherland, a graduate student at the University of Utah, became the pioneer of computer graphics and in 1965, he published a paper '*The ultimate display*' which included his prediction that a day would come when interactive computers would lead to the creation of virtual worlds (Gutierrez, Vexo, & Thalmann, 2008). He further created a head-mounted display which tracked the viewer and adjusted the graphics display in order to correctly reflect the new viewing position in 1968. He wanted the graphics to be changing in accordance with the location of the user, thus his discovery of the head sensor which was capable of measuring the position and the angle of the user's head (Gutierrez, Vexo, & Thalmann, 2008; Scheinerman, 2009).

In 1970, researchers from MIT developed what was called the *Aspen Movie Map*, which allowed users to view a simulated ride through the city of Aspen, Colorado. In this system, photographs of all the streets were captured using four cameras pointing in four different directions and mounted on a truck. In the 1970s Myron Krueger (Gutierrez, Vexo, & Thalmann, 2008) developed environments that allowed for interactive environments that catered for participation in a computer even with the full body. This type of virtualization was made possible by creating hardware that allowed for users to interact with a mechanical manipulator (Pantelidis, 1993). In the mid-1980s computer advances allowed for the development of head-mounted displays and optic-wired gloves (McLellan, 1991). True virtual reality systems were created in the 1980s when different technologies were used by researchers at NASA's Ames Research center where a pilot training system for manned space flights was being tested. The

researchers' efforts led to the development of the virtual interface environment workstation which comprised modern equipment used today (Gutierrez, Vexo, & Thalmann, 2008).

Virtual reality research has also included education and training from kindergarten to college and from college to industry. As an instructional tool, computers have been used successfully in education for many years. Computer-aided instruction (CAI) is derived from programmed instruction, based on behaviorist psychology (Deubel, 2003). This kind of instruction is capable of branching a student's instruction to different frames of information based on responses to carefully designed questions. Within the area of CAI lies the technology of computer-aided simulations. They are interactive and can give the user the feeling of presence in the environment and, thus, enhance the user's learning experience (Pantelidis, 1993). Computer-assisted simulations allow users to try different options and then decide which option completes the task at hand most effectively. Pantelidis further wrote that computer-assisted simulations can be highly motivating since there is no room for users to be passive.

Virtual instruction uses highly interactive computer-based multimedia environment in which the user takes the role of a participant with the computer in a "virtually real world" (Pantelidis, 1993). Virtual simulations have the potential to enhance and improve learning by enabling the user to interact with the virtual environment. These interactions can provide an experience that is transferable to non-virtual reality (Henderson, 1991). Virtual realities can also be used to provide motivation to the users, to accurately illustrate features using different means; give insights based on new perspectives; and allow users to manipulate and rearrange graphic symbols for easy understanding (Pantelidis, 2010).

## **Elements of a Virtual Reality System**

A virtual reality system comprises the following components: (a) input processor, (b) simulation processor, and (c) the world database. Figure 3 shows the architecture of a virtual reality system.

### **Input Processor**

This is used to control the devices used to input information to the computer. Its objective is to get the coordinate data to the rest of the system with minimal lag time. It uses the keyboard, mouse and 3D position trackers and also voice recognition.

### **Simulation Processor**

This is the core of the virtual reality system. It takes user input along with other programmed tasks into the world and determines that actions that will take place in the virtual world.

### **Rendering Processor**

The rendering processor creates the sensations that are regarded as the output to the user. Separate rendering processes are used for vision, auditory and other sensory systems. Each individual renderer responds to a description from the simulation process or directly from world database the for each time step.

### **World Database**

This stores the objects that inhabit the virtual world and scripts that describe the actions of the objects

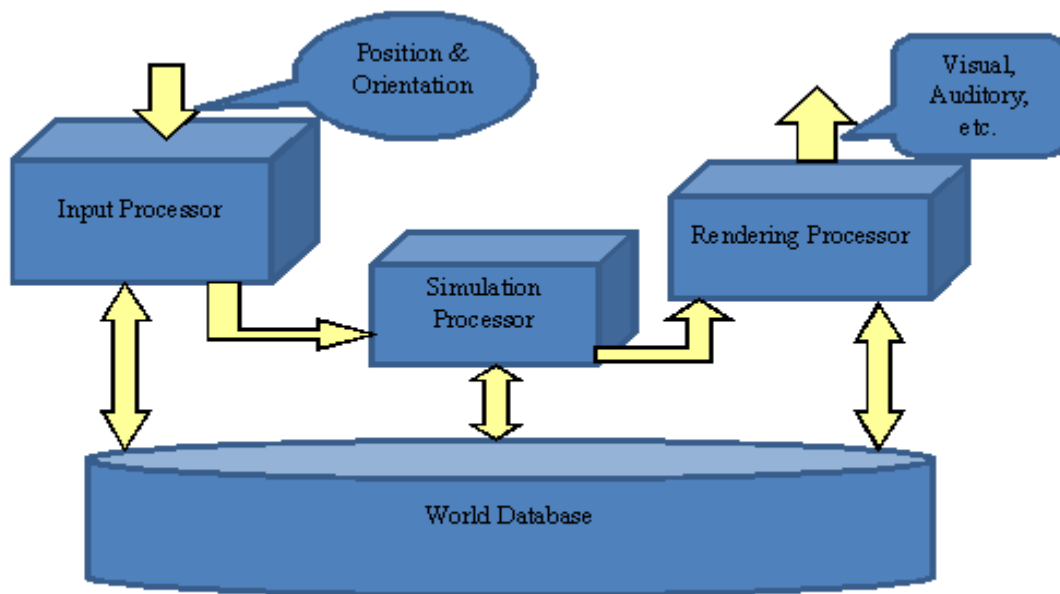


Figure 3. Elements of a Virtual Reality System. Adapted from <http://vr.isdale.com/WhatIsVR/frames/WhatIsVR4.1.html>

### Types of Virtual Reality Systems

Virtual realities can be divided into three groups: immersive, non-immersive and hybrid systems.

#### Immersive Virtual Reality System

An immersive virtual reality system is one in which the user becomes immersed in the activities of the virtual world with computer generated images.

#### Non-immersive Virtual Reality System

In this system, the user is aware of the real world and is able to observe the virtual world through the aid of a display device such as a computer workstation. In this environment, while being aware of his or her surrounding, the user can navigate the virtual environment by way of using devices such as a computer mouse which allows interaction with the devices being used (Vince, 1995; Bowman et al., 2008).

### **Hybrid Virtual Reality System**

This is the idea of seamlessly merging real world objects into virtual space. It involves the integration of computer-generated virtual objects into the physical world and makes them an equal part of the natural environment. A hybrid system allows the user to view the real world having virtual images superimposed over his or her view (Vince, 1995; Retik et al., 2002). According to Vince, augmented realities are also used by fighter pilots to have a clear view of terrains and targets captured by their head mounted devices.

### **Virtual Realities as a Training Tool**

Virtual reality (VR) refers to the use of interactive simulated environments filled with computer-generated images that respond to human movements to enable users to participate in activities similar to what they would do in the real world (Weiss, Kizony, Feintuch, & Katz, 2006). Virtual reality has also been defined as the human experience of observing and relating with the help of sensors and visual aids with a simulated environment, and with simulated objects in it, making the user feel their presence in the virtual environment by means of a communication medium acting as if they were real (Null & Jenkins, 1993; Riva, 2007). The main goal of virtual realities is to try creating an illusion for the user to think that he or she is in a tangible environment with enough interactivity and comfort (Gutierrez, Vexo, & Thalmann, 2008).

### **Applications of Virtual Realities**

There are many applications for virtual realities in the world today. However, virtual realities find wide application in the following fields of human endeavor: architecture, training, medicine, engineering design, and military.



## Architecture

Architectural design is one area in which virtual reality has tremendous potential. Currently, architectural designs are being created to allow designers and clients to examine their homes and office buildings inside and out before they have been built. With virtual reality, designers have been interactively testing a building before construction begins and should there be need for modifications, they have been learning that from their virtual models and designs. In architectural design, virtual realities can also be used to create virtual objects like historical museums, archaeological sites, virtual cities and virtual restaurants (Vince, 2004). With architecture students and teachers, virtual realities have allowed them to explore their projects from all angles and see all the tiny details and discuss the perceived design errors while still in the virtual world (Dvorak, Hamata, Skacilik, & Benes, 2005). Figure 4 shows the application of virtual realities in architecture.



*Figure 4.* A Virtual Architectural Model Promoting a High-rise Condominium. Retrieved from [http://en.wikipedia.org/wiki/Architectural\\_model](http://en.wikipedia.org/wiki/Architectural_model)

## Training

In the United States of America, the military has been using virtual realities to simulate flights and training their pilots. An organization prominent in the use of virtual realities has been the National Aeronautics and Space Administration (NASA), which used virtual reality technology to build a model of the Hubble Space Telescope (HST) in 1993. With this technology they were able to train close to 100 members of the NASA HST flight team for over 200 hours using the virtual realities (Loftin et al, 1994). Also, the US military and other militaries around the world use virtual reality models of enemy terrain to prepare their soldiers in case they have to go to war in that particular environment. Currently, virtual realities are used in driving simulators, ship simulators, and even tank simulators (Powell & Noseworthy, 2012).

Figure 5 shows the application of virtual realities in military flight training.



*Figure 5.* The Use of Virtual Realities for Military Flight Training. Retrieved from [http://en.wikipedia.org/wiki/Flight\\_simulator#Military\\_simulators](http://en.wikipedia.org/wiki/Flight_simulator#Military_simulators)

## Medicine

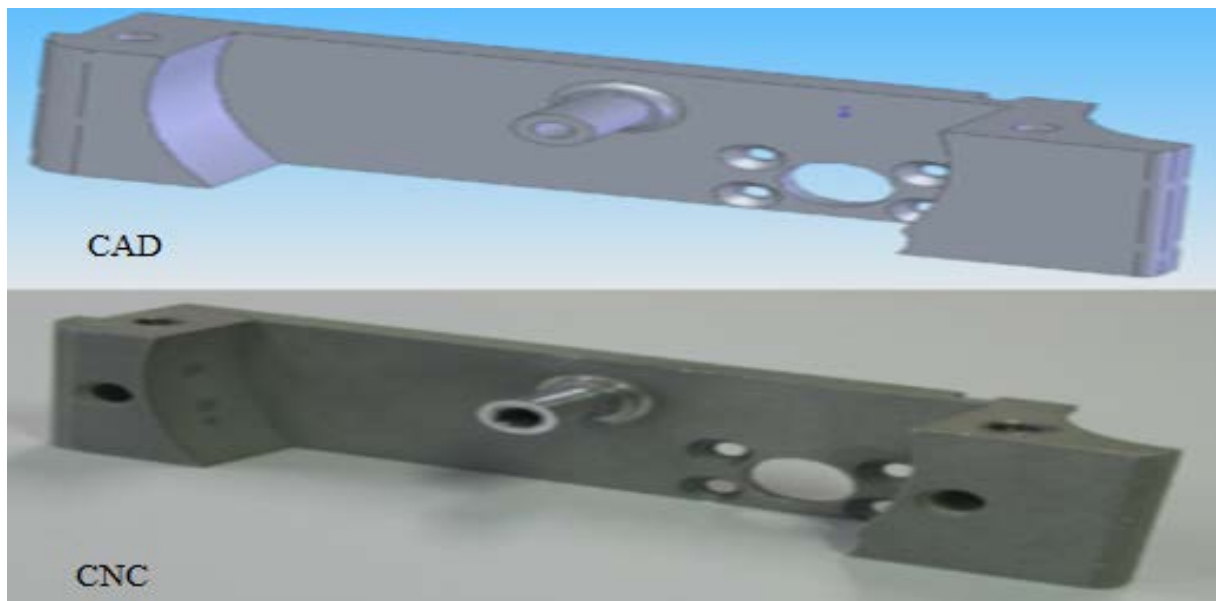
Medicine is another field in which virtual reality technology have a significant application. With the help of virtual realities, researchers are able to create 3D ultrasound images to help doctors diagnose and treat illnesses and other defects in people. The medical application of VR was necessitated by the need for medical personnel to have a visual picture of medical information during surgery, while planning for surgery and for medical education and training. In medicine, virtual realities are used to teach medical students new skills by performing complex medical procedures on virtual organs without actually harming real patients (Vince, 2004). Figure 6 shows the application of virtual realities in medicine.



*Figure 6.* The Use of Virtual Realities in Medicine. Retrieved from [http://en.wikipedia.org/wiki/Virtual\\_simulation](http://en.wikipedia.org/wiki/Virtual_simulation)

## Engineering Design

In engineering and design, virtual realities are used as part of the design process in the manipulation of 3D modeling tools and visualization techniques. This technology allows designers to first see their project in 3D, understand how it works and detect any errors or potential problems before implementation (Vince, 2004). By doing so, engineering design teams can observe their project from a safe environment and make the necessary alterations where needed. Some of the uses of virtual realities in engineering and design include car design, railroad construction design, and airplane design. Figure 7 shows the engineering design of a mechanical piece, first by virtual computer-aided design (CAD) software and then by a computer numerical control (CNC) machine.



*Figure 7.* The Use of Virtual Realities in Engineering and Manufacturing. Retrieved from [http://en.wikipedia.org/wiki/Computer\\_Aided\\_Manufacturing](http://en.wikipedia.org/wiki/Computer_Aided_Manufacturing)

## Military

Military uses of virtual reality technology include flight simulation, battlefield simulation, and battlefield training for medics. On a medical note, in order to help military

personnel to cope with their post-traumatic stress disorder (PTSD), virtual realities are used to treat soldiers suffering from battlefield trauma and other psychological conditions to deal with their symptoms in a relatively safe environment (Gerardi, Cukor, Difede, Rizzo & Rothbaum, 2010; McLay, McBrien, Wiederhold, & Wiederhold, 2010 ). This gives them enough exposure to the triggers of their PTSD, which they gradually adjust to by virtue of being immersed in the virtual environment. While immersed in the environment, they are able to reenact an incidence of encountering an enemy in an environment where they first experienced the encounter, but without real world risks. Figure 8 shows the use of virtual realities to treat PTSD.



*Figure 8.* The Use of Virtual Reality Combat Simulations as Treatment for PTSD. Retrieved from [http://en.wikipedia.org/wiki/Virtual\\_reality](http://en.wikipedia.org/wiki/Virtual_reality)

### **Current Trends in Virtual Learning**

There are several trends in e-learning technology nowadays. Amongst the current trends are that more and more people are able to create their content and then use it to learn as well as teach others. Some of the trends include the application of e-learning technologies for games, mobile phone applications, and miniaturization of educational content and social collaborations.

## **Mobile Applications**

With the advent of mobile devices which can be accessed anywhere and at any time, the e-learning industry has also sought to use the potential of mobile devices to expand their markets. What is good about mobile gadgets like smartphones, mini laptops, and tablets is that they are easy to carry and they are convenient due to their direct access to online learning resources. Mobile devices make it convenient for people who are busy working at a given work site to have training and support at times that are convenient to them (Schofield, West, & Taylor, 2011). The features of mobile devices have prompted e-learning organizations to create content that is compatible with the mobile devices by way of creating mobile applications, sometimes referred to as apps, which are able to replicate on a smartphone or tablet, what a computer at home can do. The apps are easy to use and their navigation and exploration are also very simple and enjoyable in such a way that once a user has them on his or her mobile device, the content on them is always available to the user with or without access to the internet. With the continued expansion of mobile learning capabilities, the evolving of newer forms of learning will continue (West & Paine, 2012).

## **Gamification**

Gamification is the integration of game dynamics into your site, service, community, content or campaign, in order to drive participation (Bunchball.com, 2010). Just like with mobile devices, the use of games for education has gained a lot of popularity in the e-learning community as well (De Freitas, 2006). The word gamification is used to describe the use of games in lessons although it does not strictly mean using actual games it means the use of gaming techniques to enhance learning. Gamification preys on people's natural desire to compete and win by including game-like characteristics as a way of enhancing training and

motivating the learners. With games, training developers have been able to apply different gaming techniques as is required in their topics or lessons. In a game-filled lesson, for example, when students participate, they can receive rewards such as points and badges and show their performance and progress to their peers which in turn elicits their peers' motivation to take part and achieve an even higher score, thereby learn at the same time.

### **Social Collaboration**

The rise of social media such as Facebook and Twitter has created an open environment with opportunities for communication and collaboration. With social integration, information is much more accessible for students and their instructors and it has become easy to share and exchange specialized knowledge and resources (Lombardi, 2007). Social media has made it easy for users to harness knowledge from different peers and even create new knowledge with people that they don't even know well. Also, social media makes it easy for users to collaborate with experts to find solutions for problems and leverage those with specialized skills to maximize efficiency, productivity and performance. Opening up these lines of communication and making dynamic connections among users has encouraged innovation and new ideas.

### **Bite-size Learning**

Because learners want their information now and right now, and because of the desire of users to use as few texts as possible to get to the information that they need, it has become the norm to make progress through the use of teaching the course using smaller chunks. This chunking has made it possible for users to retain information when they process and reflect on it given in small chunks (Ericson & Kintsch, 1995). The chunks of information have been in the forms of videos, podcasts and quizzes. These activities have been able to support and expand on the sources of course material thereby allowing instructors a way to break up content and engage

learners rather than by just using text alone. The convenience of mobile coupled with smaller pieces of learning material provides an opportunity for quick access to important learning materials, especially if the learner is not at school at all times.

The trend toward mobile applications, gamification, social collaboration and bite-size e-learning seems to show a shift from traditional to a more dynamic and fun-filled learning experience with greater opportunities for student engagement and participation.

### **Cloud Computing**

Cloud computing refers to the use of internet resources to access data on a remotely located computer (Kuo, 2011). An increasing number of platforms for creating and hosting learning experiences are web-based, however with cloud computing, the software can only be accessed online in a “cloud” instead of on a regular desktop. What happens when cloud computing is that a user can put all his or her files on the cloud and the cloud will serve as a storage facility as well as a working space. This is helpful in situations where the user may have forgotten a flash disk at home and wants to have access to the files as soon as possible.

### **Benefits Associated With Virtual Learning**

There are several different benefits associated with virtual learning. These include: (a) flexibility, (b) collaboration, (c) expanding educational access, (d) providing high-quality learning opportunities, (e) allowing for educational choice, and (f) achieving administrative efficiency.

### **Flexibility**

As opposed to the classroom based type of learning, virtual learning provides a number of different educational opportunities for both the learner and the instructor and the most important benefit would be that of its flexible nature where students can enroll in a class at any



time of their choosing (Koller, Harvey, & Magnotta, n.d.). It is the flexible nature which serves to attract learners who usually have strict schedules at their places of work and cannot manage to attend the regular school setting (Farrel, 1999). Learners can enroll in a course at any time, unlike the case with classroom based learning where enrollment is always at the beginning of a semester. Learners who are enrolled in a virtual classroom enjoy the learning because it is student-centered and all the attention is focused on their learning. This further allows students to own the learning process because they are the ones in charge of the learning and get inspiration for self-reliant (Sparrow, Sparrow, & Swan, 2000).

### **Collaboration**

Collaborative learning can also take place in a virtual learning environment. Similar to classroom group work, virtual learning also gives opportunities for students to learn in groups, thereby rendering them to be more active participants in the learning as they engage in critical thinking and problem-solving activities (Brindley, Blaschke, & Walti, 2009). Collaboration in the virtual learning environment allows participation in discussions and problem-solving sessions. Results of such discussions can lead to shared ownership among the learners as opposed to ownership by one particular individual (Brindley, Blaschke, & Walti, 2009). Shared ownership of the learning can lead to building strong bonds among the learners, which in itself can help create knowledge and develop critical thinking skills (Brookfield, 1995; Christensen & Dirkinick-Holmfeld, 1996).

### **Access to Global Resources**

Because every resource can be found online by simply logging on to a computer that is connected to the internet, it has become easy for students learning virtually to access to materials and even interact with subject-matter experts in relevant fields of their learning from any location

in the world (Twigg, 1995). This ensures that learners can fulfill their learning obligations at any time and they are accorded the chance to overcome the challenges presented by geographical locations to gain access to the education they desire (Barbour & Reeves, 2009).

### **Expanding Educational Access**

Innovations in computer-aided technologies have had significant impacts on education globally and these impacts have in turn caused legislation concerning technology-based education to become one of the trending global policy discussions across nations of the world (Barbour & Reeves, 2009; Selwyn, Gorard, & Williams, 2001). International agencies such as the United Nations Development Program (UNDP) promote ICTs as tools for addressing socio-economic problems. In the same vein, the United Nations Educational, Scientific and Cultural Organization (UNESCO) support the use of ICTs for facilitating the modernization of education, especially in developing nations. An example of this is the Rwandan government's proposal to make Rwanda into a technology and communications hub and to use the internet to transform the country from an agricultural society to a knowledge-based one by the year 2020. To achieve its goals, Rwanda has constructed an optic fiber network worth US\$95 million (Fiber Optic Mania, 2011), an investment which demonstrates a firm belief in the ability of the Internet to promote national development. Internet technology has been particularly advocated because of its potential for increasing the reach of education and expanding school access beyond the traditional classroom. This has created new avenues for universities to recruit from a new population of students who they might otherwise not have reached due to their remote locations (Clothey, 2008). Foreign-based students who are not able to obtain a visa to go and study abroad have now found it easy to stay at home and learn from the institution they would have gone to for studies if they had been granted a visa. This in turn has led to the reduction of the exodus of

much needed brainpower to other countries which might have rendered their countries under skilled.

### **Administrative Efficiency**

Virtual learning has added a new dimension to administrative efficiency. Flexible work schedules and efficient performance of duties is now possible for people involved in the administration of virtual learning management systems because they can monitor activities of students and instructors as they occur and then render solutions to problems almost immediately as they arise (Barbour & Reeves, 2009; Pardo, 2012).

### **Challenges Associated with Using Virtual Laboratories**

During the course of this literature review, very little information was found that directly related to challenges faced by instructors who use virtual. What the researcher did find were issues pertinent to online learning. To a certain degree these issues also relate to the setting of virtual labs. Some of the challenges associated with online learning that are cited in the literature include lack of social interaction (social presence), instructor immediacy, equity and accessibility to technology, learning styles, and high cost of equipment.

### **Social Presence**

Social presence is a construct which pertains to the extent of interpersonal contact that exists among learners and between learners and instructors which is associated with comfortable and increased learning (Lowenthal, 2009; Stodel, Thompson, & MacDonald, 2006). The two concepts associated with social presence are the concept of intimacy and the concept of immediacy. Short, Williams, and Christie (1976) suggested that the social presence of a communications medium contributed to the level of intimacy which depended on factors such as physical distance, eye contact and smiling. However, some researchers (Rovai, Wighting, &

Liu, 2005) contended that psychological distance in the online learning environment resulted in students being isolated and frustrated and this in turn led to the high drop-out rates among learners who were enrolled in online programs. On the other hand, Ascough (2007) found that creating online social communities fostered a collaborative environment which brought about positive course grades and success in online courses.

From the perceptions of lack of social presence in online learning, it has become imperative for instructors to focus more on student-leaning curricula which take into account the needs of the learners and to react to their needs with a high sense of immediacy. Instructor immediacy is a measure of the psychological distance, which exists between a communicator and the object of communication (Fazioli, 2009). Immediacy can be conveyed by use of signs and verbal cues as well as non-verbal cues (Russo & Benson, 2005) to enhance social presence in online learning because of the tendency of learners to feel that even though their instructor is not physically present, the instructor's immediate responses to the questions that arise make it seem like the instructor is physically present (Joyce & Brown, 2009). When studying the experiences of online distance learners, Howland & Moore (2002) revealed that the students had no confidence in whether they could figure out the requirements of the assignments and they felt that they needed to be guided verbally, which went to show that there was an instructor immediacy aspect missing.

### **Equity and Accessibility to Technology**

For learners who are not technologically savvy, they find their virtual programs to be a bit of a technological burden especially if a given virtual program comes with need for a lot of technological manipulation. If such moments are encountered, technology becomes a barrier as opposed to an enabler because it delays the learning process and learners with weak

technological knowledge suffer a lot of frustrations. These frustrations can lead to students failing to turn in assignments on time and may even lead to dropping the course (Sife, Lwoga, & Sanga, 2007).

If there is an economic barrier to access computer technology resources, then the eventual result will be the exclusion of potential suitable learners from the course, an ingredient without which a virtual instruction program cannot succeed. Therefore, to be successful in the virtual learning environment, both the learners and the instructors must have access to computer technology and possess a certain minimum level of computer literacy (Palloff & Pratt, 2000). At a minimum, this literacy should include being comfortable in operating a computer and having the ability to use different computer programs (ISTE, 1998). They must also be able to communicate through writing, speaking up when problems arise (Howland & Moore 2002; Huber & Lowry 2003), and demonstrate self-motivation and self-discipline by committing enough time to course work every week (Mandernach, Donnelly, & Dailey-Hebert, 2006).

### **Learning Styles**

When developing instruction, one important thing to remember is that individuals learn differently and there are different attitudes and behaviors which determine how they prefer to learn (Gibson, 2005; Honey & Mumford, 1992). Having knowledge of students' learning preferences may provide instructors with a better understanding of their students, thereby gaining special advantage when it comes to preparing and explaining learning materials (Graf, Kinshuk, & Liu 2009). In addition, Felder & Brent (2005) found that having knowledge of one's learning style can assist a student to determine if he or she can be successful in a virtual learning environment.

## **High Cost of Equipment**

Virtual programs are expensive, so expensive that schools find virtual learning can be costlier than campus-based learning (Staker & Horn, 2012). Although virtual programs have cost savings such as not needing physical buildings, equipment, materials, and other facilities; the savings is augmented by the initial and continual costs of hardware, software, internet connectivity, and other infrastructure elements. As a consequence, for many virtual students, studying virtually imposes a financial burden, which translates in to a drain on family finances or a student loan debt.

## **Challenges for Developing and Implementing Virtual Learning Environments**

Virtual learning environments (VLEs) are the most commonly used information communication technologies (ICTs) to support traditional learning in higher education institutions in the world today (Romero, Ventura, & Garcia, 2008). Challenges associated with developing and implementing VLEs relate to both teachers and students.

### **Challenges Associated With Teachers**

Major challenges for developing and implementing virtual learning environments associated with teachers include their resistance to change, inadequate technological confidence, and lack of motivation and commitment.

**Teacher resistance.** In a study conducted by McPherson and Nunes (2006) it was found that one of the main reasons teachers resisted change from traditional teaching to teaching in a virtual environment was due to not including them in the early decision-making process. The teachers were rarely consulted in the move to integrate virtual teaching/learning. The result was heavy resistance from the teachers. In 2010 Shorrt found that the same problem existed in a high school in Ireland where after four years of trying to get teachers involved in teaching in a virtual

environment they were still experiencing resistance, mainly because the teachers had never been involved in the deciding and planning to do so.

**Technological confidence.** Success of a virtual learning environment depends a great deal on the confidence teachers have in their ability to use computers and related technology. (Ertmer & Ottenbreit-Leftwich, 2010). The confidence of the teacher not only has an impact on the teacher's ability to teach in this environment, but it also influences student motivation and confidence in the teacher (Kwofie & Henten, 2011).

**Motivation and commitment.** In 2002, Carlson found that teachers lacked motivation and commitment to using the virtual learning environment when they felt ill-prepared to do so. Special teacher preparation regarding how to use this type of environment is essential in order to have teachers motivated and committed. This preparation must relate to how to use virtual learning environment technology and the various teaching methods, strategies, and techniques that work in this environment (Ertmer & Ottenbreit-Leftwich, 2010).

### **Challenges Associated With Students**

Major challenges for developing and implementing virtual learning environments associated with students include lack of motivation, inadequate funding, lack of academic confidence, and lack of technological confidence.

**Lack of motivation.** Motivation is defined as the amount of effort a person is willing to exert toward the achievement of a particular goal (Schaffer, 2008). It is also the force that is responsible for arousal, selection, direction and continuation of behavior (Biehler & Snowman, 1993). According to Williams and Williams (2011), if students are not motivated it is very difficult for them to learn and, therefore, their motivation is an important part of the successful implementation of any type of learning.

Lack of student motivation to be successful in virtual learning may result from a number of factors. It can come from students experiencing continual breakdown in hardware and/or software. It can be caused by having to work with slow computers (Zafeiriou, Nunes, & Ford, 2001). It may also result from delayed teacher feedback regarding work on their assignments (Dzakira & Idrus, 2003). When planning and implementing virtual learning, care must be taken to ensure that enough resources are provided to use state of the art hardware and software, as well as highly qualified and motivated teachers that are committed to doing everything humanly possible for making this type of learning environment to work.

### **Qualitative Research Interviews**

The main purpose of qualitative research interviews is to get a glimpse of the world from the subjects' phenomenological experiences and construct meaning from them (Kvale, 1996). Interviews used for research differ from other kinds of interviews because other than being merely a conversation, they are used to enhance intellectual understanding of people's lived experiences with regards to a specific topic (Kvale, 1996). Cohen, Manion, and Morrison (2000) explained that "... the interview is not simply concerned with collecting data about life: it is part of life, itself, its human embeddedness is inescapable" (p. 267). The role of the researcher when interviewing is to ask questions that are able to elicit valuable information and valuable responses from respondents (Smith, Jarman, & Osborn, 1999). With regards to what the interview questions need to be like, Hoyle, Harris and Judd (2002) wrote that interview questions have "... dual goals of motivating the respondent to give full and precise replies while avoiding biases stemming from social desirability, conformity, or other constructs of disinterest" (p.144). Gray (2004) suggested the following reasons for using interviews to collect data and for using them as a research instrument:



1. There is a need to attain highly personalized data;
2. There are opportunities required for probing;
3. A good return rate is important, and;

### **Types of Interviews**

There are several types of interviews, including:

1. Structured interviews,
2. Semi-structured interviews, and
3. Unstructured interviews.

**Structured interviews.** These are types of interviews in which questions are prepared before the interview and every participant is asked the same questions framed in the same manner and asked with probing questions of the same intensity (Smith, Jarman, & Osbourne, 1999). Usually, these types of interviews are used when the information about the subject under investigation is already known having been gathered through a different type of interview.

Corbetta (2003) defined structured interviews as: "... interviews in which all respondents are asked the same questions with the same wording and in the same sequence" (p. 269). The achievement of an ideal situation where interviews are conducted as defined by Corbetta is only possible when the interviewer uses the same tone of voice in order not to influence the participants when there is a change of tone in speaking (Gray, 2004). Bryman (2001) explained that a structured interview involved:

... the administration of an interview schedule by an interviewer. The aim is for all interviewees to be given exactly the same context of questioning. This means that each respondent receives exactly the same interview stimulus as any other. The goal of this style of interview is to ensure that interviewees' replies can be aggregated .... Questions

are usually very specific and very often the interviewee a fixed range of answers. (p. 107)

**Semi-structured interviews.** In this type of interview there is flexibility for the interviewer and interviewee and the interviewer uses an interview guide to conduct the interview (Bryman & Bell, 2007; Kumar, 1989). There is no specific theory that the interviewer seeks to test when using this type of interview (David & Sutton, 2004). Instead, open-ended questions are used in the form of an interview guide in which the order of questioning can be rearranged in order to suit the flow of the interview conversation (Flick, 1998; Kajornboon, 2005). The flexibility of this type of interview is such that if during the course of the interview the interview participant's responses are contradicting, the interviewer will need to ask the participant to elaborate for clarity (Finlay, 2005). In this regard, it will be important for the interviewer to have undergone thorough training in the methods of interviewing before conducting interviews (Burke & Miller, 2001; Sommer & Sommer, 1997). There is no specific hypothesis that the interviewer seeks to test when using this type of interview (David & Sutton, 2004). Corbetta (2003) considered semi-structured interviews to be interviews where:

“...The order in which the various topics are dealt with and the wording of the questions are left to the interviewer's discretion. Within each topic, the interviewer is free to conduct the conversation as he thinks fit, to ask the questions he deems appropriate in the words he considers best, to give explanation and ask for clarification if the answer is not clear, to prompt the respondent to elucidate further if necessary, and to establish his own style of conversation. It is flexible, but usually a given set of questions is covered, varying levels of standardization” (p. 270).

The open-endedness of this type of interview allows for the interviewer to have the leeway for further probing for more information from the interview participant. The most important feature of probing is the chance it accords the interviewer to ask questions that were not initially included for consideration (Gray, 2004). Qualitative interview data analysis is mainly focused on the creation of codes, themes and sub-themes which make it easier for the researcher to analyze the data which has been gathered (Zhang & Wildemuth, 2009). According to David & Sutton (2004), having "... key themes and sub-questions in advance lies in giving the researcher a sense of order from which to draw questions from unplanned encounters" (p. 87).

**Unstructured interviews.** This type of interview is non-directed and is a flexible method in which the need to follow an interview guide is disregarded and the interview participants are encouraged to speak as open as possible about their experiences to provide information that is valuable to the interviewer (Kajornboon, 2005). Like the case with semi-structured interviews, there are no theories that the researcher seeks to prove about the subject under inquiry, instead, the researcher talks with the interview participants and in the process formulates questions related to the interview participants' accounts (Patton, 2002; Zhang & Wildemuth, 2009). In unstructured interviews the researcher asks questions that may not even be relevant to the topic just to make the interview participant open up about the subject being researched. Probing questions are used to encourage to the participant to keep talking or to get back to the subject of interest (Smith, Jarman, & Osborn, 1999). During the course of the unstructured interview, the researcher is usually exposed to unexpected themes which in turn help to come up with a better appreciation of the interview participants' lived experience (Polkinghorne, 2005). While all this is happening, the researcher does not lose focus and keeps in mind the purpose of the interview and the general scope of the topics being discussed.

Because of their interactive nature, unstructured interviews, call for the person using them to be experienced and skilled in the art of interviewing (Corbin & Morse, 2003).

### **Summary**

In this chapter, the researcher detailed the literature review on topics relevant to the research, which included: (a) constructivism, (b) the use of technology in teaching, (c) virtual realities and their applications, (d) benefits and challenges associated with virtual labs, and (d) the use of qualitative research interviews for data gathering. Chapter 3 will outline the methodology of the research and the data collection tools used. Chapter 4 will contain a discussion of the findings of the research. Chapter 5 will feature the conclusions, discussion, and recommendations based on the findings in Chapter 4.

## **Chapter 3: Methodology**

The main purpose of this study was the identification of benefits and challenges associated with using virtual laboratories, the solutions for overcoming the challenges, and factors to consider when planning the development and implementation of virtual labs in developing countries like Zambia or in communities that have limited financial resources.

### **Statement of the Problem**

Because of the severe inadequacies of training laboratories in Zambian schools and the fact that there is not enough laboratory space to meet the demand for laboratory experiences, there is a need to develop and implement virtual labs.

### **Research Questions**

The following research questions guided the design and the methodology of this study:

1. What are the benefits associated with using virtual labs?
2. What are the challenges associated with developing and implementing a virtual lab?
3. What are the challenges associated with using virtual labs to teach on a day-to-day basis?
4. What solutions can be used to overcome the challenges associated with developing and implementing a virtual lab?
5. What solutions can be used to overcome the challenges associated with using virtual labs to teach on a day-to-day basis?
6. What factors should be considered when planning the development and implementation of virtual labs

### **Design of the Study and Participant Selection**

To answer the research questions, a qualitative research design that included interviews was deemed to be best suited to collect data from participants. The researcher used interviews

because of the need to get in-depth phenomenological views of the research participants with regard to their experiences with virtual labs.

The researcher interviewed a total of 15 participants, comprising: (a) three research participants from New River Community College; (b) one research participant from Loudoun County Public Schools; (c) one research participant from Newport News Public Schools; (d) three participants from the Montgomery County Public Schools; (e) two from Giles County Public Schools and; (f) five from Roanoke County Public Schools. The main factor considered when selecting participants were their experiences associated with planning, implementing, and using virtual labs. There were seven female and eight male participants. All of them had attended college. Three had Ph.D. degrees and the rest had master's degrees. All of these institutions had vibrant career and technical education (CTE) programs that provided courses in which virtual labs played a significant role in the learning process. Table 1 shows the institutions and number of years of teaching experience of the teachers and administrators who took part in the research.

Table 1

*Organization and Participant Positions and Years of Experience*

<b>Organization</b>	<b>Position</b>	<b>No. of Years with Virtual Lab Experience</b>
Public School System 1	Administrator: 1 Teachers: 2	Administrator: 7 years Teacher 1: 5 years Teacher 2: 4 years
Public School System 2	Teachers: 2	Teacher 1: 5 years Teacher 2: 9 years
Public School System 3	Administrator: 1 Teachers: 1	Administrator: 5 years Teacher 1: 2 years
Public School System 4	Administrator: 1	Administrator: 15 years
Public School System 5	Teachers: 2	Teacher 1: 7 years Teacher 2: 7 years
Public School System 6	Teachers: 1	Teacher 1: 3 years
Public School System 7	Administrator: 1	Administrator: 7 years
College Institution	Administrator: 1 Teachers: 2	Administrator: 17 years Teacher 1: 18 years Teacher 2: 24 years

The teachers were selected based on recommendations from the CTE program administrators. The researcher first identified and interviewed CTE administrators who in turn gave advice and direction about possible teachers to be interviewed. CTE administrators were relied upon to identify the teachers because they had adequate information about who was using virtual labs and the schools in which they were based. Approval was obtained from each participant's CTE administrator for their participation in the study. After approval from the CTE administrators, the researcher contacted the teachers first by email and then by telephone to make an appointment for explaining the purpose of the research study in person. This was followed by

making an appointment to return and interview the participants who had agreed to be interviewed. Appendices D and E show samples of emails used to recruit the administrators and teachers.

The teachers had to meet the following criteria:

1. Must have been using virtual labs at least twice a week or throughout the year or as the primary mode of instruction in one grading period;
2. Must have had more than a year's experience in using virtual labs;
3. Must have been consistent with the use of the virtual labs in their classrooms, and
4. Must have been actively serving as teachers at the time of the study.

The CTE administrators had to meet the following criteria:

1. Experience in assisting teachers to develop and implement virtual labs;
2. Experience in assisting teachers to select software for virtual labs, and;
3. Experience in supervising teachers who use virtual labs.

Current or former administrators were deemed to be admissible as research participants because their experience was what was important to the researcher.

### **Pilot Study**

Prior to conducting the actual study, a pilot study was conducted to determine any deficiencies in the research interview instrument or procedures. In order to conduct the pilot study, two teachers who used virtual labs and one CTE administrator were interviewed. They were from institutions different from where the researcher conducted his final interviews. The pilot study was also used to determine the reliability and validity of the questions used on the instrument.



## **Results of the Pilot Study**

After getting all the responses from the three participants, an aggregation of the responses was made and this led to the implementation of effective changes to the final research instrument. The pilot study participants suggested that the researcher should remove the question: **“What daily challenges have your teachers faced while using virtual labs?”** from the CTE administrators’ protocol because it created an ambiguity since the teachers were not expecting to face challenges every day. The same sentiment was expressed with regard to this question on the CTE teachers’ interview protocol: **“What daily challenges have you faced while using virtual labs?”** The two different questions related to challenges were merged to make one general question to identify overall challenges. Upon revising the interview questions based on recommendations from the pilot study participants, both interview protocols were deemed sufficient for the research study to begin.

## **Research Interview Question Protocols**

There were two separate research instruments (one for the teachers and another for the CTE administrators), each with 22 interview questions structured around the six research questions. The interviews were recorded using a digital recorder, then transcribed and coded. Emerging themes were identified and organized with the help of NVivo (a data analysis software described in the data collection section) to group the responses in order to have a clear understanding of problems and solutions. Copies of the research instruments may be seen in appendices A and B respectively.

## **Data Collection**

In order to record and facilitate the face-to-face interviews, the researcher employed a digital recorder, a laptop computer, and a notepad. Digital audio recording allowed the

researcher to revisit the records of the interview time after time whenever necessary to confirm accuracy of the records. The field notes were written mainly in short form, comprising key phrases, major points, and key terms. They assisted the researcher in developing probing questions. As each interview progressed further, the researcher was able to formulate additional questions whose themes were in tandem with the main question. This was done to probe the interview participant for further clarifications. At the end of the interview sessions, the researcher went home and took time to go over the records thoroughly and make comparisons between the recorded data and the field notes. The audio recordings were then transcribed into text using computer software so that the researcher could create codes and themes, at the same time ensuring the anonymity of interviewees.

The method used to analyze data utilized the four basic techniques of grounded theory, namely: (a) coding data, (b) using constant comparison, (c) theoretical sampling, and (d) data synthesis. In order to fully understand the research participants' responses, the researcher used the synchronous and recursive (Charmaz, 2006) process. The researcher started the analysis by coding after transcribing the first interview in order to identify concepts that were repetitive in the data. These concepts in turn led to the formation of themes of the responses. The constant comparison technique was done while the researcher was coding, which enabled a different way of forming categories and identifying the different points of analysis. Using the constant comparative method allowed the researcher to establish the basis for the validity of the study and demonstrated the dependent relationship between the data collected and the analysis of results. The researcher continued the recursive process until the data were saturated and there were no more new categories that could be developed from the data. Finally, the constant comparative method was used to create a comprehensive account of the benefits and challenges associated

with using virtual labs and solutions used to overcome them, thereby rendering the phenomenological descriptions of the research participants to be consistent with themes and categories derived from the their accounts.

The researcher chose NVivo software, which was provided by Virginia Tech to graduate students and faculty. An NVivo project database is made up of several folders and files. According to Bazeley (2007), there are 5 principal ways in which NVivo supports analysis of qualitative data. Bazeley wrote that using NVivo software allows the researcher to:

1. Manage data - to organize and keep track of the many messy records that go into making a qualitative project. These might include not just raw data files from interviews, questionnaires, focus groups or field observations, but also published research, other documentary sources, rough notes and ideas jotted into memos, information about data sources, and conceptual maps of what is going on in the data;
2. Manage ideas - to organize and provide rapid access to conceptual and theoretical knowledge that has been generated in the course of the study, as well as the data which supports it, while at the same time retaining ready access to the context from which those data have come;
3. Query data - to ask simple or complex questions of the data, and have the program retrieve from its database all information relevant to determining an answer to those questions. Results of queries are saved to allow further interrogation, and so querying or searching becomes part of an ongoing enquiry process;
4. Graphically model - to show cases, ideas or concepts being built from the data, and the relationships between them, and to present those ideas and conclusions in visual displays using models and matrices; and

5. Report from the data - using contents of the qualitative database, including information about and in the original data sources, the ideas and knowledge developed from them, and the process by which these outcomes were reached. (p. 2).

When the NVivo software was installed on the researcher's computer, it automatically created a folder ready to store various types of information. The NVivo software served as storage for the data and it enabled the researcher to constantly check the information in collected. While analyzing the transcriptions, the researcher determined the meanings and relationships of the responses given by the interview participants.

### **Adherence to Research Ethics**

Ethical issues such as informed consent, confidentiality, and consequences for the interviewee were taken into account and shared with the participants. In addition, they were informed about the purpose of the investigation and the procedures to be followed and were ensured of strict confidentiality. Each participant was requested to sign a consent form indicating their willingness to participate. A copy of the consent form may be found in Appendix C. In addition, the study was first approved by the Virginia Tech's Institutional Review Board (IRB). Data collection began near the end of September, 2012, and was completed by the end of December, 2012.

### **Validity and Reliability**

Triangulation is the mixing of data or methods so that diverse viewpoints give information about a topic. Triangulation is typically a strategy for improving the validity and reliability of research or evaluation of findings. In this research, triangulation was achieved through interviewing CTE administrators and teachers from different institutions of learning regarding their experiences with virtual labs. The researcher also used triangulation within to

make visible perspectives that were common and distinct to members within a group and between groups. Although it was difficult, while interviewing, to triangulate among multiple sources of data the way that qualitative researchers advocate, the researcher tried to get multiple perspectives on the same issues through the same interview. This was achieved by asking participants' views on a particular point, then asking a line of questions directly about that point, using another line of questions about a related issue, slipping in some references to the point into that line, and inserting a third line of questions about practices that are relevant to the point as well.

### **Generalizability and Transferability**

Despite the positive features of qualitative research, it has continued to be criticized for lack of objectivity and generalizability. Generalizability is defined as the extent to which the findings can be generalized from a study sample to the entire population (Polit & Hungler, 1991). While qualitative studies are not generalizable in the direct sense of the word, they have other mitigating features, such as partial generalizations, which make them highly valuable in the education community (Myers, 2000). Furthermore, the results of a study can be transferable to other settings. As noted by Lincoln and Guba (1986), a distinctive characteristic of qualitative research is that of transferability. Readers of qualitative research study reports can analyze the results and determine for themselves if they can be generalized to their own setting. Therefore, it is felt that the results of this study can be applicable to other settings to the extent that the readers of the results can make their own determination concerning transferability.

### **Summary**

In this chapter, the researcher detailed the methodological approach (qualitative interviews), design of the interview questions and how they were structured, the procedures

taken when going to collect data, and the eventual analysis of the outcomes this study. Chapter 4 will contain a discussion of the findings of the research. Chapter 5 will feature the conclusions, discussion, and recommendations based on the findings.

## **Chapter 4: Research Findings**

In this chapter, the researcher presents the findings of the study based on the data collected and supporting evidence from the literature review. The chapter is divided into five sections: (a) data generation, (b) characteristics of research participants, (c) data collection and analysis, (d) findings of the study, and (e) summary. The data from the 15 interviews were examined as guided by the six research questions, which focused on:

1. The benefits associated with using virtual labs;
2. The challenges associated with developing and implementing a virtual lab;
3. The challenges associated with using virtual labs to teach on a day-to-day basis;
4. Solutions to the challenges associated with developing and implementing a virtual lab;
5. Solutions to the challenges associated with using virtual labs to teach on a day-to-day basis, and;
6. Factors to consider when planning the development and implementation of virtual labs.

### **Data Generation**

This section is a discussion of how the data of the study were generated. As stated in Chapter 3, five career and technical education (CTE) administrators and ten CTE teachers were interviewed. All of the teachers and administrators participating in the study had to meet selected criteria in order to participate in the study.

The teachers had to meet the following criteria:

1. Must have been using virtual labs at least twice a week or in one grading period;
2. Must have had more than a year's experience in using virtual labs;
3. Must have been consistent with the use of the virtual labs in their classrooms, and
4. Must have been actively serving as teachers.

The CTE administrators had to meet the following criteria:

1. Experience in assisting teachers to develop and implement virtual labs;
2. Experience in assisting teachers to select software for virtual labs, and;
3. Experience in supervising teachers who use virtual labs.

### **Characteristics of the Research Participants**

The researcher interviewed a total of 15 participants, comprising: (a) three research participants from New River Community College; (b) one research participant from Loudoun County Public Schools; (c) one research participant from Newport News Public Schools; (d) three participants from Montgomery County Public Schools; (e) two from Giles County Public Schools; and (f) five from Roanoke County Public Schools. The main factor considered when selecting participants were their experiences associated with planning, implementing, and using virtual labs. There were seven female and eight male participants. All of them had attended college. Three had Ph.D. degrees and the rest had master's degrees. All of these institutions had vibrant CTE programs that provided courses in which virtual labs played a significant role in the learning process.

### **Data Collection and Analysis**

The researcher asked all the research participants to provide a set of answers for each of the questions based on what their experiences were regarding the use of virtual labs. Overall, the interview protocol had 22 questions.

This chapter will focus on the research participants' interview responses. Very little editing of the audiotape transcriptions was done. For the purposes of clarity, the following changes were made to the original audio texts:

1. Correction of grammatical errors;



2. Removal of long pauses;
3. Deletion of repeated phrases;
4. Deletion of filler sounds such as “um”, “eh”, and “like”.

When references were made to institutions and/or individuals, their names were withheld to ensure anonymity. Likewise, to ensure the research participants’ anonymity, the interview transcripts are represented by numbers instead of their actual names. In order to distinguish the research participants, administrators were designated as research participants 1-5 and teachers were assigned numbers 6-15.

### **Findings for the Research Questions**

#### **Research Question 1: Benefits of Virtual Labs**

What are the benefits associated with using virtual labs? The first research question on the interview protocol asked the research participants (both administrators and teachers) to identify the benefits associated with the use of virtual labs. Table 2 presents the main themes included in the research participants’ responses to the first question.

Table 2

*Benefits of Virtual Labs as Perceived by both Administrators and Teachers*

- 
1. Flexibility
  2. Convenience
  3. Hands-on learning
- 

**Flexibility.** The most common benefit of virtual learning is that it allows for flexibility, which in turn helps to move the focus from teacher-centered learning to student-centered learning (Lin, Ho, Sadiq, & Orłowska, 2002). The virtual labs were said to be flexible by allowing students to pace themselves and to experiment with no one knowing when they were

incorrect. During the course of the interviews, research participants were asked to describe the benefits they had experienced when using virtual labs. The respondents indicated that virtual labs were beneficial because of the flexibility of the programs and the ability for the teachers to teach the entire class at once instead of continually going back to teach concepts again and again. The virtual labs also allow teachers to save time and be able to articulate information to their students in a more succinct way (Research Participant # 10). Other researchers have written that the most important benefit associated with using virtual labs is that it provide hands-on training for students, which in turn happens to be the most effective way to increase the speed of learning technical subjects (Wallace, 2003). Virtual labs also have the advantage of allowing both teachers and students to work at home on their own time. Students can also do their assignments at different times of the day.

Some research participants made the following observations:

- The students actually have a job during the day time and they come at night sometimes and they can't get here in time to do the classes, some of the labs and that kind of stuff. So they (virtual labs) do help them prepare, you know, outside the class to be more flexible, I guess would be the right word (Research Participant # 2).
- I think some of my teachers do virtual because they enjoy the flexibility that virtual labs allow. They enjoy the fact that students can pace themselves to get through a course (Research Participant # 4).
- Virtual labs allowed kids to move at their own pace, it reduced anxiety I think because it allowed them to try to answer the questions and if they were wrong, no one knew but them (Research Participant # 12).

**Convenience.** Another benefit associated with using virtual labs is that it gives students time to do their lab work at their own convenience, allowing them to prepare for class at home (Research Participant # 2). Unlike the traditional lab in which students would have to be following instructions rigidly, virtual labs are considered to be convenient and flexible because they allow students to do experiments on their own and at their own pace (Muhamad, Zaman, &

Ahmad, 2010). This argument was also supported by Foertsch, Moses, Strikwerda, and Litzkow (2002) when they were describing the features of their eTEACH virtual software. There was a feature in the eTEACH software that allowed students to pause a lecture and consult other resources if they were having difficulties understanding a concept, thereby enabling them to watch their lectures at their own pace.

Comments illustrating the benefits of convenience as perceived by the research participants were:

- It saves me a lot of money because they burn up less stuff, like they do in computer simulations in electronics, micro instrumentation (Research Participant # 2).
- Students can work at their own pace. Students can access their school work from home (Research Participant # 7)
- It is also easier for a teacher to explain using a virtual lab because in most cases a teacher would have a graphic representation of what he or she would be talking about (Research Participant # 6).
- It allows me to teach the entire class one time, instead of going back (Research Participant # 10)

**Hands-on learning.** Although a virtual laboratory may not be entirely equivalent to a physical laboratory, the benefits that it offers cannot be easily ignored (Carnevale, 2003). When studying the impact of the Virtual ChemLab project, Woodfield et al. (2004) concluded that students obtained hands-on experience without having exposed themselves to harmful chemical substances. According to the research participants, virtual labs are a form of hands-on learning since students learn while they are doing their lab work. Because this happens in a virtual collaborative space, students learn from trial and error, which encourages thinking and motivation and provides opportunities to complete learning activities that are virtually guided by the instructor. Also, having students work on virtual projects in small groups facilitates

balancing student participation by increasing participation from reserved students (Warschauer, 1997; Attaran, & VanLaar, 2001).

Comments illustrating hands-on learning in virtual labs as perceived by the research participants were:

- I think it's giving kids an opportunity for self-exploratory learning experiences. Because, again the whole purpose is not just to have them sit down and work on computers all day, every day. It allows them (students) to perform something hands-on independently besides a regular project. (Research Participant # 3).
- Virtual labs are a great supplemental teaching. I don't think they were designed to replace the hands-on stuff and the hard technologies (Research Participant # 2).
- We are using online software for our family consumer science program and our technology education programs. One, I see student engagement. Students, as many of the researchers say, like to do hands-on activities. So you see students engaging, but you also see instructional strategies that teachers used to help with classroom management and instruction (Research Participant # 5).
- I am a strong proponent of active engaged learning experience where you are using your hands and your eyes, your mind and body as much as you possibly can (Research Participant # 1).

### **Research Questions 2 and 3: Challenges Associated with using Virtual Labs**

What are the challenges associated with developing and implementing a virtual lab?

What are the challenges associated with using virtual labs to teach on a day-to-day basis?

Research questions 2 and 3 were tackled by question 2 (a through f) and question 3 (a through d) on the interview protocol. These questions yielded two sets of challenges from the two categories of research participants. The challenges were divided into those faced by administrators and those faced by teachers. Table 3 below provides the lists of challenges associated with developing and implementing a virtual lab as perceived by the research participants.

Table 3

*Challenges Associated with Developing and Implementing a Virtual Lab*

Challenges faced by administrators	Challenges faced by teachers
1. Teacher preparation	1. Student competency
2. Technological changes	2. Equipment failure and software inconsistency
3. Software problems	3. Lack of communication
4. Teacher resistance to curriculum changes	4. Lack of adequate training

**Challenges Faced by CTE Administrators**

**Teacher preparation.** The administrators reported that most of the time when they try to development and implement a virtual lab in one of their CTE programs, they have a difficult time finding a teacher who is conversant with the software they are going to use in their virtual labs, has the knowledge and understanding of course materials, has the knowledge of and skills for using virtual environment teaching methodologies, and has the necessary technical competence for using the hardware needed in the virtual lab. Therefore, teacher preparation was identified as a challenge for successfully developing and implementing virtual labs. The timing of teacher preparation is critical and finding individuals who can prepare teachers is also difficult.

This challenge was supported by Palloff and Pratt (2001), who stated that teachers starting a new virtual course (lab) for the first time should not be expected to use their intuition to know how to design and deliver an effective virtual course; rather, they need to be exposed to the techniques and methodologies necessary to successfully work in this environment.

Comments illustrating the challenge of inadequate teacher preparation as perceived by the research participants were:

- Any computer based program that I have rolled out to all of my teachers, there have been problems with implementation because of the teachers' ability to understand and utilize technology... Sometimes it is the teacher preparation; sometimes teachers are not ready to actively manage a virtual situation (Research Participant # 1).
- We didn't realize that the teachers had to be trained how to become the facilitators. We actually thought that a teacher could understand a lab concept but we've had some situations where teachers will sit at their desks on their computers instead of actually monitoring students closely. So it was a big disconnect from a teacher still feeling like they are teaching instead of just allowing the computer system to teach (Research Participant # 4).
- Challenges are teachers' expertise in technology. Many of them don't know how to use it. When I say don't know how to use it, they are not so familiar with using kind of online systems and most of them are very easy (Research Participant # 5).

**Technological changes.** Rapid change in hardware and software technology was also identified as a challenge administrators faced when developing and implementing a virtual lab in one of their CTE programs. Whenever there was a slight change in the software, it meant that funds had to be secured to train teachers on how to use the new software. Many times changes in software required changes in hardware that could operate the new software. The pace at which the technology changed made it very difficult for administrators to keep up and required them to constantly look for resources to support the changes. As reported by Fullan and Smith (1999), changes in technology are a challenge to keep up with because during the implementation of new technologies, teachers go through an implementation difficulty in the first stage of transition, regardless of whether there is support or not.

Comments illustrating the challenge of technological changes as perceived by the research participants were:

- Keeping up with the technology, keeping up with making sure that we have the most updated software and the hardware refreshes match because often if you upgrade to a software package you need to have something additional that you might not have in older machines (Research Participant # 3).
- We are at the mercy of the curriculum vendor or provider; we are at the mercy of the internet connection and dependability of that connection. And in a high school setting where we still have kids in very discrete blocks of time and place, if we have technical problems, it's very disruptive of a process (Research Participant # 1).
- It is very difficult for teachers to keep up with changing technology depending on how much the external forces are pushing them to change platforms. Sometimes (our business labs are a prime example) the external market changes the software requirements, which thus changes the hardware requirements and there are learning curves involved with each of these steps for that teacher to continue teaching the product they prefer because of the continuous change (Research Participant # 2).

**Software problems.** Although virtual learning has many benefits, technical challenges are some of the disadvantages of entirely relying on the use of this medium to teach (Sitzmann, Ely, Bell, & Bauer, 2010). Software problems were also cited as some of the challenges the administrators faced. They reported that labs failed at the time when they were expected to work, thereby leading to the frustrations of both the administrators and the teachers. Software problems also have a negative effect on achieving program training goals (Webster & Hackley, 1997). Students often feel they are wasting time when there are continual problems with the software they are using (Wentling, Park, & Pieper, 2007). Many times this can even lead to students dropping out of the course. In addition, some of the teachers were found to have been uncomfortable with the virtual learning platform because of anticipated software problems.

Participants made the following comments to illustrate problems relating to software:

- There is not a lot of stuff out there. Finding the stuff that is applicable to what you need, and is targeted towards your audience as opposed to the virtual stuff they use for industry (Research Participant # 2).
- You know software issues obviously sometimes, we have some of our virtual labs use trainers that you have to hook up with the virtual lab and sometimes

they don't always work like they are supposed to. They give us some headache sometimes (Research Participant # 3).

- Continuity and consistency in the software and making sure that the steps work. Not having proper instructional material provided by companies that produce the software is the most frustrating thing on earth. That is the day-to-day thing that really can be frustrating-not having consistent tools or the proper tools. (Research Participant # 5).

**Teacher resistance to curriculum changes.** Having all teachers to embrace the change from teaching in a traditional environment to a virtual one was often quite a challenge for the administrators participating in the study. They found that some of their teachers resisted the change because they were much more comfortable teaching in the traditional environment. In a similar manner, Whipp and Chiarelli (2004) reported that those who were new to online teaching experienced uneasiness with regard to their ability to handle the technical, organizational, and social challenges which came with the online environment. Furthermore, according to Morris (2010), resistance to curricular change is mainly caused by a teacher's perception of the new course materials, the goals with which it comes and the underlying philosophies behind the course or the new medium of teaching.

Teaching not only demands a lot of time and effort from teachers to develop the curriculum for online courses, but to also learn the new technologies which come with the new medium of teaching (Grosse, 2004; Lorenzetti, 2004 as cited in Keengwe & Kidd, 2010). The aspect of having to introduce new technologies to teachers brings about apprehension and in some instances even frustrations because the teachers become resistive as they are worried about the demands of time and further planning, with which the new courses will come (Matsom, 2006, as cited in Keengwe & Kidd, 2010). Resistance to curricular change is mainly caused by a teacher's perception of the new course materials, the goals with which it comes and the underlying philosophies behind the course or the new medium of teaching (Herron, 1971;



Morris, 2010). In this regard, any change that is brought into a school and is met with resistance from teachers has no chance of succeeding (Hinde, 2004).

Comments illustrating teacher resistance and curriculum readiness as perceived by the research participants were:

- I mean, the challenge I face is resistance. You put the lab in there but they won't use it. Because they are not comfortable with it; they don't like technology; they don't like computers (Research Participant # 5).
- Some teachers do miss the fact of being able to stand up and deliver instruction. So those teachers battle with the virtual situation because they miss the methods that many of them were trained to do throughout their educational training. So that has been a disconnection at times between my teachers who don't necessarily enjoy virtual lab situations (Research Participant # 4).
- One of the challenges is they lose focus because they have so many students at so many different levels and you don't have a group of students that are tracking together (Research Participant # 2).

### **Challenges Faced by CTE Teachers**

**Student competency.** The teachers reported having to face similar challenges as those identified by the administrators. They mentioned that the students they had in their classes did not have the necessary competencies in the use of computers and in mathematics. The lack of these skills created problems for both the teachers and the students because valuable time was diverted toward teaching computer skills and mathematics at the expense of teaching the course content. Ensuring that laboratory equipment was ready for a class session was also reported as a challenge because there were times when there was a lack of coordination between the teachers and the departments responsible for the administration of the virtual programs. Student grade levels also posed a challenge because they felt that some students were just too young to keep up with the demands of using virtual labs. Similarly, Smith, Ferguson and Caris (2002) stated that virtual courses are labor-intensive, intellectually

challenging, and elicit deeper thinking on the part of the students, qualities that the young students did not have. The majority of students were not ready for the virtual learning curriculum as some of them were too young to understand the virtual learning environment itself.

Comments illustrating the challenge of student competency as perceived by the research participants were:

- Well, I must say that it has been a nightmare. The grade level of the students in this particular class is too low to appreciate or understand the material in the class. The maturity level and age of the students plays a huge part in the success the student has with the class (Research Participant # 7).
- The daily challenges that I come up with are students that don't have the competencies in the computer use, so they have problems with that. Mathematical incompetency, they (students) have trouble with math portions of it, figuring calculations, figuring formulas, so I have to basically overcome those challenges before I can run the labs effectively (Research Participant # 6).
- I mean that's beyond the scope of what my students need to learn--they just need to pretty much be able to get on to the program, and know how to work the program, know how to troubleshoot it (Research Participant # 8).
- And that's one of the things I have learned through the course of this is that the students certainly do not know as much as we think they do when they come in (Research Participant # 9).

**Equipment failure and software inconsistency.** Frequent malfunctioning of lab equipment was also one of the challenges teachers faced when using virtual labs. As Buckenmeyer (2008) noted, these malfunctions lead to stress in teachers especially when their queries are not answered promptly. There was also lack of proper continuity of virtual software for the teachers to smoothly transition to using a newer version of the existing software. This put the teacher in the position of being at the mercy of other people's assistance at times, and this assistance hardly ever came as soon as it was needed. Therefore the teachers felt that using the computers without technical support was challenging and discouraging (Darus & Luin, 2008).

This was worse when compounded with the slow rate at which the virtual information was coming to the students.

To illustrate the challenges relating to equipment failure and software inconsistency, some research participants made the following comments:

- Continuity and consistency in the software and making sure that the steps work. Not having proper instructional material provided by companies that produce the software is the most frustrating thing on earth (Research Participant # 10).
- The networking issues and that stuff which is really more through our division than anything, and that whole learning curve that we have all gone through (Research Participant # 9).
- Difficulties are usually technical in nature. First, you have to have access to computers and software. Then, you have to hope that nothing breaks down, or the internet doesn't go down, in my case (Research Participant # 12).

**Lack of communication.** As with the administrators, the teachers identified that a lack of communication between the teachers and the schools technology expert often presented a challenge. They indicated that sometimes the expert was not available when immediate assistance was needed to solve a problem. They also said there were times when the technical expert took too long to ensure that laboratory equipment was ready to use for a given lab session. All of these delays created frustration for the teachers because they were dealing with frustrated and sometimes impatient students.

Comments illustrating lack of communication between the teachers and the technology centers as perceived by research participants were:

- Major challenges include the coordination of contact between the virtual headquarters and me. Another major challenge is the equipment and making it ready for the virtual class (Research Participant # 7).
- Some of the daily challenges include, you know, technology issues, whether or not the server is up or down or you know, students submitting assignments, you know normally they'll track how long someone has been on there but the problem is that the tracking, if they have more than one course, is just tracking how long they were

on the computer program (Research Participant # 8).

- We've also had some networking issues within our own division with certain programs and learning modules, so that has been a definite learning curve for all of us, and especially our TRT (Technology Resource Team) guys, our technology guys, there's been a learning curve with that (Research Participant # 9).
- Sometimes we do not communicate well with the individuals who are supposed to help us when we have technical problems. To me, these are some of the challenges--communication (Research Participant # 15).

**Lack of adequate training.** Getting the necessary training for specific virtual lab software was also a challenge for some of the teachers interviewed. In some cases, there were very few hours devoted to training the teachers, who in turn were ill-prepared to train their students on how to use the specific lab. Because of the small amount of time spent on training teachers initially, teachers were forced to find their own time to train themselves to understand the software better and then effectively utilize it.

Comments illustrating lack of adequate teacher training as perceived by the research participants were:

- The experience that I have had as far as problems is getting the training that I need and basically I have to train myself on most of them. Like the machines that I showed you here in the lab. So that's one problem that I have had-- getting enough training and enough time to get that and be effective with it (Research Participant # 6).
- The experience that I have had as far as problems is getting the training that I need and basically I have to train myself on most of them (machines). Like the machines that I showed you here in the lab. So once I have developed the training and I am confident with it, then I convey that to the students. So that's one problem that I have had--getting enough training and enough time to get that and be effective with it (Research Participant # 10).
- We do not have enough training in virtual teaching. It is like these things are dumped on us without consultation and adequate training (Research Participant # 15).

## Research Questions 4 and 5: Solutions to Overcome Challenges

What solutions can be used to overcome the challenges associated with developing and implementing a virtual lab? What solutions can be used to overcome the challenges associated with using virtual labs to teach on a day-to-day basis? Research questions four and five were tackled by question 4 (a through c) of the interview protocol. The responses were merged into one section despite being responses to two different questions because they addressed solutions to overcoming challenges, whether the challenges are in the implementation stage or during the day-to-day operations of a virtual lab. Table 4 provides the research participants' recommended solutions to the challenges associated with developing and implementing a virtual lab as well as the solutions to overcome the challenges associated with the day-to-day operations of the lab.

Table 4

*Solutions to Overcome the Challenges Associated with Developing and Implementing a Virtual Lab.*

Administrators' solutions	Teachers' solutions
1. Funding for training	1. Collaboration
2. Technical support	2. Training
	3. Alternative plans
	4. Student competency

### Administrators' Solutions

**Funding for training.** Making funds available for new equipment, software updates, and training was one of the solutions mentioned by all the administrators interviewed. Provision of funding for staff development was considered to be important for the smooth operation of the virtual programs in the various schools because the training helped teachers acquire the skills

needed to develop, implement, and use virtual labs. In the case of Research Participant #3, this administrator hired a lead technology teacher who went around the labs when he was not teaching and checked on the labs and the production areas that had virtual learning equipment. This person also checked equipment prior to classes to ensure that everything was working before the students came into class. All the administrators stressed the importance of training their teachers as being one of the first actions they took to solve the problems that were encountered by teachers who used virtual labs. Training involved bringing software vendors to the schools and colleges to train the teachers in the effective operation of the virtual software. Other forms of training included sending teachers to relevant conferences so that they could go and interact with other teachers as well as book publishers and software developers to discuss various software packages and how they were being used. Since teachers spend most of their time working in isolation from one another, they need to have access to other people from whom they can learn. These people can either be experts or a common group of peers who put their efforts together and share their research findings with one another (Curtis & Lawson, 2001).

Comments illustrating the importance of funding and training as perceived by the research participants were:

- As I said before, I use our internal trainers very actively to train teachers on the platforms we are using, the software we are using. I have industry trainers come in when I have a group of teachers needing to learn about a new product. I have the person who sold, or developed a product come to these teachers and teach them how to use it more effectively (Research Participant # 1).
- I would do a presentation there at the “*New Horizon Conference*” and all these folks will attend. I send my entire faculty, as many as possible, to the conference to gain insight and to network, I guess, if you will, with the other colleges to get information on what it’s like. And they always have the vendors there selling the virtual software, selling the textbooks, selling the, whatever they may use in greatest and biggest software (Research Participant # 2).

- If we have an individual who has gone through the training and still can't get it, then we have the vendor come and work with them one on one, and we get the principal to support bringing in a substitute. If there's a technology problem, we have a recording system and we have people who are specifically trained to our modules in instructional technology, who target their efforts towards problem solving, what's going on. So it's really is one on one if someone is still having challenges (Research Participant # 3).
- I did last year have a teacher that I saw wasn't really using it to the capacity and so what I did was offer a training--a refresher--with the actual vendor. I had them come in for a whole day workshop and work with them (Research Participant # 5).

**Technical support.** Providing technical support to teachers who need help is important for the smooth operation of educational technology. Also, providing professional development helps teachers to learn how to use the technologies in their classrooms. This in turn allows them enough time to create and plan their instruction so as to provide constructive feedback to students (Keeler & Horney, 2007; McQuiggan, 2007). Other than just giving teachers the instructional tools that would assist them, the administrators reported that they tried to do ongoing training with the help of the technical staff in the school.

The following are some of the comments made by research participants about the provision of technical support:

- You just need to make sure that you have a good technical support staff that understands the product, understands some of the links, like knowing that if you upgrade software, XP might have a factor in that. If you go to upgrade to explorer 7, or 8 or 9, that can have implications on all the software. Someone who really knows your product and has been through the training gets it so that they can help the teachers troubleshoot. Because, if it's not working, it's not working and it slows everything down (Research Participant # 3).
- Fortunately we have a robust technology department with technical resource teachers in each and every building so we rely on them heavily to answer teachers' questions and maintain their systems, both software, hardware and internet systems so that they are productively in use and to train teachers on technologies that are needed on an individualized basis (Research Participant # 1).

- We have very good supportive IT people here who actually help us in the analysis and stuff of whether that's good software; we get like a 30-day period test kind of thing and the fact that they are through, and make sure that is exactly what they want, and all that kind of stuff before they purchase the software (Research Participant # 2).

## Teachers' Solutions

**Collaboration.** Working together with other teachers who teach the same course/class was reported to be one of the solutions teachers used to overcome the challenges they faced while using virtual labs. This was done by being in constant communication with all the people involved in the teaching/learning process, including those who were busy researching ways in which the teachers could share their teaching experiences (Curtis & Lawson, 2001).

Collaboration was achieved by joining an online listserv, a teachers' blog or any educators' forum that had the capabilities of letting members ask their technologically savvy peers questions and then share their successes with others (Kingsley, 2007).

Comments illustrating collaboration as perceived by the research participants were:

- Constant communication with whether, if it's the student, the counselor in our school, or if a student has taken my course or an administrator that I am having issues with, parents, and constant communication with the company itself (Research Participant # 9).
- One of the main things I was able to do was collaborate with other teachers teaching the same class. These teachers may have been in my school or somewhere else in the state that were also teaching the course. I have also tried to stay in constant contact with the folks at the DOE (Department of Education) (Research Participant # 7).
- What I do is collaborate with other teachers so as to find out what problems they have encountered and how they have solved them (Research Participant # 15).

Collaboration was also used by teachers to ensure that they were adhering to the established standards of learning as implied by research participant # 9.



**Training.** When technology changes, it requires those using the technology to keep up with the changes and acquire new skills. Essential training is absolutely necessary to prepare teachers for using the new technology and accepting “new” values and behaviors that result from the technological changes (Attaran & VanLar, 2001). The teachers reported that they took advantage of training opportunities if and when they were availed to them. When selecting new software, they made sure that training was available to learn how to use the software before making a commitment to purchase it, an important precautionary solution to potential challenges.

Comments illustrating the solution of teacher training as perceived by the research participants were:

- So my solution is really getting to know the software very, very well, and knowing my students and what their capabilities are (Research Participant # 9).
- The experience that I have had as far as problems are getting the training that I need and basically I have to train myself on most of them. Like the machines that I showed you here in the lab. So once I have developed the training and I am confident with it then I convey that to the students (Research Participant # 6).
- Also, attending professional development on different technologies because again, the more you know about technology, the easier it is to transfer knowledge from one to another (Research Participant # 12).

On a similar note, the following is a comment made by an administrator who used such a solution:

- We offer all kinds of classes for instructors to take. How they integrate all this, like apple, the apple iPad, how they do this, how to, you know everybody has the best practice that they tell a way how to talk about, so it’s very progressive (Research Participant # 2).

**Alternative plans.** For teachers who envisioned difficulties with the failure of equipment, they had devised back up plans in order to ensure that their lessons continued uninterrupted (Lipscomb, 2003). These plans were in the form of handouts, other types of written materials, and compact discs. In addition, the teachers said when experiencing a

software problem on a given topic and not having time to immediately fix the problem, they simply skipped that topic and went on to another topic for which the software worked. They then fixed the problem after class and taught the skipped topic another day. In other cases, the teachers worked together with the technical support in their schools to solve their challenges.

Comments illustrating the alternative plans teachers made as perceived by the research participants were:

- Also whenever technology might be down where they are working on it at school and the server is down, then I'll also have handouts just to supplement. So that was the solutions I did, so just in case it's not there, then I'll always have that backup where I can actually get up and teach the stuff (Research Participant # 8).
- Whenever we were doing this in class today, I'd say, okay guys, this didn't work, so give me a time out, give me 10 minutes and let me look for a solution. It's like if I don't get it right now, I will get it. I am sure that frustrates students but it is what it is, I can't wave a magic wand and say fix. So you just have to keep a positive mindset at all times and understand that there are going to be failures. That there are going to be roadblocks and you just have to realize that, when you hit those, you look for an alternative route to make things work (Research Participant # 10).

To further emphasize the importance of having alternative plans, the administrators made the following comments:

- We teach the course, but it's in a classroom. Rather than doing the virtual labs online, what we do is do the virtual lab in the classroom so that when students do the lab, then they will go and physically build it (Research Participant # 2).
- Actually, we restructured and we made them not a 100% virtual but a hybrid of virtual mixed with traditional methods. So for the classes that we had a hard time getting the students engaged in the content, we actually pull back a little bit and we actually have a piece of the course virtual, another component being traditional (Research Participant # 4).

**Student competency.** Although many students are found to be competent enough to learn through virtual labs, the teachers reported that for those that were not, it was due to

inadequate reading, math, and computer skills, an argument also supported by Jaggars (2011). Because there are students who cannot learn through virtual labs, it was felt by some research participants that a student identification process should be used to identify those students who can best learn from virtual labs. For students who cannot learn best from virtual labs, a different delivery method should be used for them. Other participants felt that anyone who wishes to take a course that uses virtual labs should be allowed to do so, regardless of their capabilities.

Comments illustrating student competency as perceived by the research participants were:

- No, it needs to be considered. It's not for every learner; it's certainly not for the learner who needs auditory learning. It's really for the intrinsically motivated, self-motivated student. I think it's a good opportunity for all students, but the students who struggle in the normal everyday setting are probably also going to struggle even more in the online setting because there is no one there constantly reminding them (Research Participant # 9).
- Most definitely. Some students just aren't self-motivated to do the work on their own. Grade level and maturity of the student needs to be considered (Research Participant # 7).
- Yes it is. They have to. As we become more and more modern as a society in manufacturing specifically, it's very important that we have students who are capable of doing this type of work (Research Participant # 6).

To further emphasize the importance of student competency, the administrators made the following comments:

- Oh, yes. It's also for everybody because every student needs to have the opportunity to experience: (1) the career and technical education class, but (2) the technology that is incorporated in that class because that is still a part of the career skills that we want them to have (Research Participant # 5)
- We've been putting every kid into a virtual situation, but in the past before the state requirement, we selected kids somewhat carefully, generally through our guidance offices that are at our high schools, we would look for students who were self-

motivated learners; who are technologically capable and ready (Research Participant # 1).

- Pre-screening them? Difficult to do. I would say no. I would put everybody in there and then. I have always found that putting pre-requisites for a course really puts up barriers for students (Research Participant # 2).

**Research Question 6: Factors to Consider When Planning Virtual Labs**

What factors should be considered when planning the development and implementation of virtual labs? On the interview protocol, question 5 (a through f) was designed to answer the sixth research question. The responses were categorized as follows: Developing considerations and implementation considerations. Table 5 provides the considerations that need to be made when planning the development and implementation of virtual labs as perceived by the research participants.

Table 5

*Factors to Consider when Planning the Development and Implementation of Virtual Labs*

<b>CTE Administrators</b>	<b>CTE Teachers</b>
Development	Development
1. Infrastructure	1. Infrastructure
2. Audience	2. Audience
Implementation	Implementation
1. Student characteristics	1. Teacher qualifications
2. Mode of delivery of instruction	

**Factors to consider when Developing Virtual Labs: CTE Administrators**

**Infrastructure considerations.** As reported by Blinco, Mason, McLean, and Wilson (2004), the term “infrastructure” does not necessarily relate only to network connections and

computers. Its elements, as related to virtual labs, include: people working with it, the computers, the building in which the labs are housed, the network connections, and the hardware and software that make the system run smoothly to allow students to conduct their lab activities. The research participants reported that it is important to know the type of infrastructure that is currently available before developing a virtual lab. Knowing this information will prevent purchasing something that will not work on the current infrastructure. It will also provide valuable information concerning what infrastructure updates will be required prior to implementing the lab, thus allowing for sound financial planning to be made. This includes updates for hardware, software, data connections, and training. Knowing how many financial resources have been budgeted for the infrastructure and how it is going to be spent is also important. Underinvestment in infrastructure, even with all the other challenges being addressed, can be a very big source of failure when implementing a virtual lab (Dube & Pare, 2001). Both teachers and administrators considered knowledge of and planning for infrastructure to be the most important step to take when introducing virtual labs.

Comments illustrating the importance of infrastructure considerations as perceived by the research participants included:

- First thing you have to determine, you have to assess your infrastructure to make sure that it will support the lab that you intend to put in place. And you need to investigate the available curriculum, and/or develop a curriculum. And then you have to familiarize your teachers with the platform and the curriculum. And instruct the teachers on how to use that curriculum (Research Participant # 1).
- We have had some issues in which we didn't realize that everybody logging in at the same time would cause some type of issues or overloads in the system. So, I think the factor that should be considered when utilizing is, what the space actually offers (Research Participant # 4).
- One of the things that I do come into difficulty with is your infrastructure. Like I have a room right now that the building is old and so it just depends on what

type of technology you already have in the building as it relates to data ports and power. You've got to keep that in mind (Research Participant # 5).

**Audience.** The research participants reported that it is important to know who the target audience will be before starting a virtual lab. Knowing who the students will be helps make one more effective at determining exactly what they need. Early in the process of developing a virtual lab, it is an administrator's responsibility to define the audience because doing so means that you are defining the audience's level of familiarity with the type of instruction and other important details necessary for the smooth operation of a virtual lab. They felt that knowing the types of students coming into the virtual program, their attributes, technological capabilities, and social standing would help in creating learning content that would cater to all of them. As stated by Pope-Ruark (2011), before planning the development of a virtual lab, it is important to know who the audience is going to be and what is going to be taught. Furthermore, according to Fein and Logan (2003), one of the most important features of instructional design is knowledge of the audience, knowing the content and also knowing what it is about your content and its mode of delivery that is going to satisfy the needs of the audience in a convincing manner.

Comments illustrating the importance of considering the intended audience as perceived by the research participants were:

- A lot of considerations. One is who your target audience is for that. Is it the freshman, the sophomore or the junior? What their capability is of learning that virtual piece of software. What do you hope to attain by using that virtual software (Research Participant # 3).
- I think the main factor is who your students are; who is sitting in front of a computer (Research participant # 4).
- And the other thing you need to consider is the technology-savvy students. Are these schools that have a high level of students with technology at home? That's going to make a difference too (Research Participant # 5).

## Factors to Consider when Developing Virtual Labs: CTE Teachers

**Infrastructure consideration.** Just like the administrators, the teachers also said that it was important to consider infrastructure before embarking on building a virtual lab. They indicated that there was need to check the laboratory equipment to ensure that the curriculum for which they were designed would work properly. Having a good idea of the amount of space available and knowing exactly where the laboratory equipment would be installed was said to be part of the infrastructure audit necessary for building a virtual lab (Magana, Astorga, Serrat, & Valle, 2009).

Comments illustrating the importance of considering the infrastructure as perceived by the teachers were:

- Consider the equipment and what the computers must have installed on them for the curriculum to run properly (Research Participant # 7).
- You want to look at space being provided, you know, whether or not you have computers for all your students. You want to also have, I guess, the bandwidth or whatever, where you can actually support every single, like if every person in the school is on the computer at a time, it should be able to support it without slowing down the system (Research Participant # 8).
- Consider the location of the building where you plan to install your computers because not all the power points you need might be ready for your computers (Research Participant # 13).

**Audience.** The teachers also reported that it was important to know who the target of the instruction was before developing a virtual lab. Knowing the types of students would help them to establish realistic measures that would relate to any intended audience, regardless of their capabilities (Smith & Ragan, 1999).

Comments illustrating the importance of considering the intended audience as perceived by the teachers were:

- We basically look at our candidates for the machine technology program; we look at where they are coming from, their background, whether they are mechanically inclined or not (Research Participant # 6).
- You might want to introduce a selection criterion so that you know who your students are and what qualifications they are coming with. It is important to know who is going to attend the class beforehand (Research Participant # 14).
- And also you need to plan for students who may not have the money to have a computer at home. Because to me that's unfair, so if anything we should have some type of laptop checkout type procedure (Research Participant # 8).

### **Considerations When Implementing Virtual Labs: Administrator Considerations**

**Student characteristics.** The administrators indicated that students entering a virtual lab setting needed to have at minimum to be successful: good math skills, be computer-savvy, be self-motivated, exhibit a sense of maturity, and possess good computer skills. However, the question of setting prerequisites for students who wanted to learn by using virtual labs yielded two sets of responses. First, about half of the participants felt that virtual labs should be all inclusive, allowing anyone to take the lab. The other half of the participants believed that students should meet certain prerequisites in order to take the lab and actually benefit from it.

It was further discovered that those participants who were in favor of all-inclusive enrollment did so because CTE programs are funded based on enrollment and not necessarily because students enrolled could actually benefit from virtual lab instruction. Both teachers and administrators thought that if the all-inclusive policy was not in place, there would not be enough students taking the lab to justify its offering, something which would also have an impact on their funding. The research participants supporting the all-inclusive policy also felt that it was important for all students to be given the experience of virtual learning because, more than likely, they would be required to learn virtually in a work setting. The participants who were supporting student selection based on prerequisites thought so because it helped them save time



and resources from being used to teach students who were not motivated to learn in the virtual lab. Also, working with students who knew what was supposed to be done and students who worked without supervision was enjoyable for them.

Comments illustrating the all-inclusive policy when selecting students for virtual learning as perceived by the research participants were:

- We have been putting every kid into a virtual situation, but in the past before the state (CTE funding based on number of students enrolled) requirement, we selected kids somewhat carefully, generally through our guidance offices that are at our high schools. We would look for students who were self-motivated learners; who are technologically capable and ready. But the self-motivated piece is probably the single most important. We still have students in high school who have an aversion to computers. We still have students in high school who have an aversion to learn and they have a very difficult time in a virtual class (Research Participant # 1).
- Difficult to do. I would say no. I would put everybody in there and then I have always found that putting pre-requisites for a course really puts up barriers for students (Research Participant # 2).
- No, because when you are looking at career and technical education, it is an elective program. Now, at our technology center, students do apply and it is a competitive application process. But that's a different program, it's a more intensified program and it's a choice. At the high schools, we want them to get an idea of career cluster areas, career pathways that's a part of that 7-year plan that we require the middle schoolers in the 7<sup>th</sup> grade to begin and to start thinking about. So, you know, it kind of varies to what your end goals are (Research Participant # 3).

On a similar note, the teacher research participants had the following remarks to make regarding student characteristics:

- I am a person for inclusions, so I think that everyone should be able to experience it because of the fact that most colleges and universities have online learning, so regardless of if you go to college or not, you have to some type of program where you have to learn some things they might require you to take online (Research Participant # 8).
- Well, at a community college, it's going to be different than a university. At a community college level, even though you as an instructor would like to be able to say, I think this is what I would prefer: somebody that has great math skills;

somebody that understands physics; somebody that can communicate well with other people-those would be my top 3. However, that's not the case. Whereas in college, for a university, you have some very specific parameters that you get to work with inside and so you have to be very flexible, and like I said, you have to learn how to teach (Research Participant # 10).

Comments below illustrate the sentiments of both administrators and teachers who thought that setting up student selection based on prerequisites was necessary:

- I think if you want it to be a successful learning environment you have to consider student selection of individual students and I think that we can train, teach and train students so that most of them can be reasonably successful in a virtual learning environment. I am not sure that 100% of them are ready to be successful (Research Participant # 1).
- It is a big part of what we try to do now. Originally, 5 years ago, we did not. Everybody went into the virtual situation and that was one of our downfalls. But now we look at the student and we try to figure out whether it is the student that has the motivation to get through a course that's being taught virtually (Research Participant # 5).
- Yes it is. They have to. As we become more and more modern as a society in manufacturing specifically, it's very important that we have students who are capable of doing this type of work (Research Participant # 6).
- Most definitely. Some students just aren't self-motivated to do the work on their own. Grade level and maturity of the student needs to be considered (Research Participant # 7).
- No, it needs to be considered. It is not for every learner; it is certainly not for the learner who needs auditory learning. It is really for the intrinsically motivated, self-motivated student. I think it is a good opportunity for all students, but the students who struggle in the normal everyday setting are probably also going to struggle even more in the virtual setting because there is no one there constantly reminding them (Research Participant # 9).

**Mode of delivery of instruction.** The research participants who were teachers suggested that virtual labs should be used as a supplement to existing physical labs because it was difficult for students to learn how to use certain machinery only by way of having done some virtual manipulations. Because of this foreseeable problem, it was suggested that a blending of virtual

labs and physical labs should be adopted. The teachers also suggested that they should know upfront what the expectations of their administrators concerning how the lab should be taught.

The recommendation by teachers to adopt a blended lab setting is supported in current literature. There are two ways in which a virtual lab can be used to deliver instruction to students; they are blended and stand-alone (Staker & Horn, 2012). In this case, blended learning is a combination of a virtual lab and a physical lab, whereas a stand-alone virtual lab is when students complete all lab requirements virtually without any use of a physical lab. By blending, Staker and Horn meant that a student learns through virtual delivery with some element of student control over time and space and at least in part at a supervised brick-and-mortar location away from home. When in a blended setting, what students learn virtually adds to the knowledge they gain when they learn face-to-face, and vice-versa. Knowing how the lab is going to be taught virtually and what skills students will have mastered at the end is important to the implementation of virtual labs. Whether the lab will be used as a stand-alone program or something blended with a classroom component should be stated from the onset so that it is clear to the students. Smetana and Bell (2006) wrote that computer simulations were not entirely intended to be used as a stand-alone component, but to supplement traditional hands-on activities because the simulations presented an opportunity to offer explanations of scientific concepts, which helped teachers and students to bring complex concepts to life. Also, having knowledge of how assessment is going to be done is a good indicator of chances of success of the program because assessment information helps the teacher to plan how to cater for the various learners in the classroom (Berry, 2006).

Comments illustrating considerations of how the virtual labs would be used in the end as perceived by the research participants were:

- I personally believe that the best virtual training is actually a blended instruction for high school students where the teacher uses a virtual classroom that augments with real classroom lessons and instructions. We can't depend on a virtual lesson a hundred percent (Research Participant # 1).
- First of all, what you need to consider if it's going to be used; do you think that virtual lab will give you the result that you want for the training that you are trying to do.? In other words, you want to make sure that the virtual labs that you are trying to purchase or use will get the training result that you want (Research Participant # 2).
- To talk to principals about what the expectations are, for how many modules kids will go through. And, I had the teachers come together years ago and set that themselves: what's reasonable, what's achievable within a semester in a middle school class while 4 to 6 is achievable within 18 weeks (Research Participant # 3).

### **Considerations When Implementing Virtual Labs: Teacher Considerations**

**Teacher qualifications.** One of the most important things to consider when implementing a virtual learning environment is teacher qualifications. As stated by Meyer and Barefield (2010), having a clear definition of the requirements for teaching in virtual reality can be helpful to the successful implementation of a virtual program because it will ensure that qualified teachers are recruited. Teaching a virtual lab is different from teaching a traditional physical lab and requires the teacher to adopt new and dynamic teaching practices (Pallof & Pratt, 2001).

The teacher research participants felt that teachers of a virtual lab should: be visionary, be able to set learning goals, be committed to teach a virtual lab, have a positive attitude toward virtual labs, have in mind the number of students he or she hopes to reach with this type of lab, have knowledge of what industry skills to teach with virtual labs, have confidence in learning how to teach this way, and have the skill sets needed to teach in a virtual environment. In addition, teachers of a virtual lab should be able to determine if the content that is to be taught is relevant, well-organized, clear, and to the point.

Comments illustrating teacher qualifications as perceived by the research participants

were:

- Same thing for us as instructor, maybe a 5-year goal would be good. Setting a goal and say what do I want my program to look in 5 years? How many students do I expect to graduate per class? Who is the industry that I am hoping to target? Once I have identified those three things then what tools can I use to plan those out? Once I have identified those tools, what is it going take for me to learn this myself so that I can competently teach that to the students and what areas can I focus on? Then I can really target specific things because it's going take years to develop skill sets in a broad enough area to where you can dip into the bag and grab different components to pull out and teach because some students are going to be able to get this way (Research participant # 10).
- Who is going to teach? What qualification do they have and how were they trained (Research Participant # 15)?

The administrators also had the following comments regarding the qualifications of the teacher:

- You need to know where the presentation is coming from, who the presenter is, and vet the material to ensure it's appropriate for the subject ought to be taught (Research Participant # 1).
- Another factor would be who is actually facilitating the lab? Whether it's the teacher's skill set; whether they are interested in actually making it work or not; if they have a positive attitude towards it; and the courses--the type of courses that's being offered in the virtual setting (Research Participant # 4).

### **Summary**

In this chapter, the researcher presented the data collected from 15 research participants, each with a CTE background, on the benefits, challenges, and solutions associated with the development and implementation of virtual labs. The following are the main issues outlined in the chapter:

1. The benefits of virtual labs, as perceived by the research participants, included:  
flexibility, convenience, hands-on learning, and student motivation.

2. The challenges as perceived by the administrators included: cost, teacher preparation, technological changes, software problems, and teacher resistance. The teachers, on the other hand, identified challenges associated with students' competency, failure of equipment, lack of adequate training, and adherence to the standards of learning.
3. The solutions to overcome the challenges offered by the administrators were funding, training, and technical support. The teachers identified collaboration, training, alternative plans, and student competency as their solutions to overcome the challenges associated with virtual labs.
4. The considerations when planning the development and implementation of virtual labs according to the administrators included the infrastructure, the audience, the kinds of students who will be in the virtual labs, and finally how that particular virtual lab would be delivered after all things had been considered during planning. On the same subject, the teachers also identified infrastructure, audience, and teacher qualifications to be important factors to consider when planning a virtual lab.

## **Chapter 5: Summary, Conclusions, Discussion, and Recommendations**

The purpose of this chapter is to present the conclusions, discussion, and recommendation of the study. In order to provide the context for the chapter, in the first two sections the researcher gives a summary of the study as well as the research questions and the methodology that was used.

### **Summary of the Study**

#### **Statement of the Problem**

Because of the severe inadequacies of training laboratories in Zambian schools and the fact that there is not enough laboratory space to meet the demand for laboratory experiences, there is a need to develop and implement virtual labs.

#### **Purpose of the Study**

The main purpose of this study was the identification of benefits and challenges associated with using virtual laboratories, the solutions for overcoming the challenges, and factors to consider when planning the development and implementation of virtual labs in developing countries like Zambia or in communities that have limited financial resources.

#### **Methodology**

To answer the research questions, a qualitative research design that included interviews was deemed to be best suited to collect data from participants. The researcher used interviews because of the need to obtain in-depth phenomenological views of the research participants with regard to their experiences with virtual labs. Participants in this research study were selected from educational institutions in Virginia, including New River Community College, Roanoke County Public Schools, City of Newport News Public Schools, Montgomery County Public Schools, Giles County Public Schools, and Loudoun County Public Schools. All of these

institutions had career and technical education (CTE) programs that provided courses in which virtual labs played a significant role in the learning process. The main factor considered when selecting participants were either their experiences associated with planning and implementing or using virtual labs. Ten CTE teachers and five CTE program administrators from different school systems and one community college were included in the research study. The CTE teachers were selected based on recommendations from the CTE program administrators.

### **Research Questions**

This study was designed to answer the following questions:

1. What are the benefits associated with using virtual labs?
2. What are the challenges associated with developing and implementing a virtual lab?
3. What are the challenges associated with using virtual labs to teach on a day-to-day basis?
4. What solutions can be used to overcome the challenges associated with developing and implementing a virtual lab?
5. What solutions can be used to overcome the challenges associated with using virtual labs to teach on a day-to-day basis?
6. What factors should be considered when planning the development and implementation of virtual labs?

### **Highlights of the Research Findings**

The following are highlights of the research findings:

1. The benefits of virtual labs, as reported by both the administrators and teachers, were:
  - a. Flexibility;
  - b. Convenience, and;
  - c. Hands-on learning.



2. The challenges as perceived by administrators included:
  - a. Teacher preparation;
  - b. Technological changes;
  - c. Software problems, and;
  - d. Teacher resistance.
3. The challenges as perceived by the teachers included:
  - a. Students competency;
  - b. Failure of equipment;
  - c. Lack of communication, and;
  - d. Lack of adequate training.
3. The solutions offered by the administrators included:
  - a. Providing funding for training and
  - b. Providing resources for technical support.
5. The teachers solutions included:
  - a. Collaboration with other teachers;
  - b. Training;
  - c. Devising alternative plans, and;
  - d. Student competency.
6. The considerations when planning the development and implementation of virtual labs, according to the research participants (both administrators and teachers) were:
  - a. Infrastructure;
  - b. The audience;
  - c. Teacher qualification;

- d. Mode of instruction, and;
- e. Student characteristics.

### **Conclusions**

The following narrative describes the conclusions of the study based on the findings presented in Chapter 4.

#### **Benefits Associated with Using Virtual Labs**

Both administrators and teachers identified the same benefits associated with using virtual labs. A major advantage of virtual labs is that of convenience. It also provides flexibility for CTE teachers to offer courses and lab experiences which are not otherwise readily available to students who need them. These labs can be offered at anytime and anywhere, provided students have access to the internet. In places where there is no internet, students should be given a disc with the virtual lab software. In addition, for those students who are learning from a virtual lab in a class setting (much like what high school students do), it allows them to be able to work on lab experiences at home. The participants also felt that virtual labs did provide hands-on learning, but not to the extent that physical labs do.

Regarding a model that best promotes the highest level of student learning, it is concluded that a blending of a virtual lab and physical lab is the best model to follow. This model is also beneficial when there is limited physical laboratory space. Students can be divided into groups, having one group work in the virtual setting while another group works in the physical lab and then trading places.

## **Challenges Associated with Developing and Implementing Virtual Labs and Using Them on a Day-to-Day Basis.**

The second and third research questions related to challenges associated with virtual labs. Since both questions related to the same issue, that being challenges, but at different stages of using these labs, the conclusions are presented together.

**CTE administrators.** As reported by administrators, the upgrading of new software has a ripple effect. When companies upgrade their software, it usually means that new computers need to be purchased to run the new software. In addition, the teachers using the new software and new computers need re-training to update their skills on how to use them. This constant cycle of change creates a tremendous challenge to find the resources needed to continually update the software and hardware and to re-train teachers. Therefore, it is concluded that when considering the development, implementation, and the day-to-day use of virtual labs, at least a five-year budget plan needs to be in place to support these continual changes.

The administrators also indicated that when trying to develop and implement a new virtual lab, it was sometimes difficult to find teachers who either had the expertise to teach in this environment or the motivation to learn how to do so. Furthermore, when they did have teachers who had less than desirable knowledge and skills, it led to problems associated with keeping students engaged in their learning. Therefore, it is concluded that when planning the development and implementation of a virtual lab, particular attention needs to be focused on getting the right person to teach the lab. The selection of this teacher is critical and will have a tremendous impact on the success of the lab.

Finally, the administrators felt that their teachers lost focus and motivation when they were confronted with having many students in their classes who were at many different levels of

technological understanding, maturity, and knowledge of basic computer skills. Sometimes it made it almost impossible to properly facilitate the lab and move students forward to accomplish the expected outcomes of the course. Therefore, it is concluded that there should be a requirement for students who wish to enroll in a virtual learning program to meet certain prerequisites prior to their enrollment. These prerequisites should relate to a student's level of technological understanding and skills, maturity, and basic academic knowledge and skills. It is in the best interest of the student and teacher to have these prerequisites and to enforce them.

**CTE teachers.** Although the challenges identified by teachers were similar to those from the administrators, as expected, their challenges focused more on the classroom level. The teacher-identified challenges related to making sure the software and hardware worked before every class session. They needed to make sure they completely understood how to use the software and had a plan to assist students in learning in a virtual environment. They also had the challenge to have a backup plan to use in case there was a breakdown in software and/or hardware during the middle of a given class. They had the challenge of moving all students forward to accomplish the intended outcomes of the course.

Therefore, it can be concluded that teaching in a virtual environment has its unique nuances, and teachers need to be provided with an adequate amount of time for class preparation and lab maintenance. This amount of time will probably be different from what is provided for individuals teaching in a traditional environment.

It is also concluded that support should be provided for teachers using the virtual environment to have up-to-date quality software and hardware that actually work. The teachers also need support (financial and sufficient time) to provide them with the initial training and re-training needed for them to be successful in teaching in a virtual environment.

Finally, it is concluded that a working communication plan between the virtual lab teacher and the school's technology specialist is critical so the two can solve technical problems quickly when they occur.

### **Solutions That Can Be Used to Overcome the Challenges**

The fourth and fifth questions related to solutions for overcoming the identified challenges. Again, since both questions related to the same issue, this time being solutions, but at different stages of using these labs, the conclusions are presented together.

**Solutions offered by CTE administrators.** The solutions offered by the administrators were similar in nature, that being providing something for teachers. They thought that funds for teacher training should be an important part of the total budget for a virtual lab. Examples of the types of training could include sending teachers to conferences and bringing software representatives to the school to train teachers. In addition to funds for training, the administrators felt that providing technical support for teachers could also assist them in overcoming challenges. This technical support can come in the form of hiring an adequate number of technical specialists to be placed at the schools where virtual labs are used. It is therefore concluded that training, re-training, and technical support be a major part of the budget for providing virtual labs in a school. This training and support is paramount in the success of operating virtual labs

**Solutions offered by CTE teachers.** The teachers also thought that training is an important means for overcoming challenges they face on a day-to-day basis. Furthermore, because of the nature of rapidly changing technology, this training should be provided on a continual basis. In addition to training, the teachers felt they could help one another overcome challenges by way of collaboration. This, in itself, is a type of training. Alternative instructional

plans provide another way to overcome challenges that are experienced on a day-to-day basis. When the technology breaks down, there needs to be backup plans to teach the lesson. Finally, the teachers indicated that it is of utmost importance to make sure that students have the adequate amount of technological competence, maturity, and basic academic competence needed to be successful in a virtual lab prior to taking the lab.

Based on these findings, it is concluded that training for teachers and technical support should always be included in the budget for operating a virtual lab. It is also concluded that time and a formal plan be provided for teachers to collaborate with one another. In addition, time should be given to teachers to allow them to devise quality alternative instructional plans. Finally, it is concluded that a student application process be put into place to determine if students wishing to take a virtual lab have the necessary prerequisites to be successful in the lab.

### **Considerations When Planning the Development and Implementation of Virtual Labs**

The sixth research question looked at the factors to consider when developing and implementing virtual labs. The administrators and teachers identified the following considerations: (a) infrastructure, (b) audience and student characteristics, (c) mode of delivery, and (d) instructor qualifications.

**Infrastructure.** According to the research participants, it is difficult to effectively develop and implement a virtual lab without first considering the infrastructure that will be needed to support the lab. Infrastructure is the foundation of a virtual lab. Without the appropriate supporting infrastructure, the best software available on the market will be useless. Information concerning the server and bandwidth that is necessary and that is available, the space needed in the virtual lab itself, as well as the electrical and ventilation outlets needed, are all examples of parts of the infrastructure that must be considered. It is therefore concluded that

the decision to move forward with developing and implementing a virtual lab should only be made after the infrastructure requirements and availability have been determined. The determination of what infrastructure is needed and what is available should be made with the consultation of technology specialists.

**Audience and student characteristics.** Both administrators and teachers felt that knowing the audience and their characteristics prior to their enrollment in a virtual lab is of great importance. Certain knowledge and skills are needed in order for students to be successful in learning from this environment. In several parts of this research report, there has been an overlap of the importance the audience and student characteristics play with regard to student success. As seen in earlier sections of the report, some of the participants were in favor of establishing and enforcing prerequisites; while others felt that enrollment figures should play a paramount role in determining who should be allowed in a virtual lab, regardless of whether or not they can be successful. It is therefore concluded that in addition to having an application process to determine eligible participants of a virtual lab, remedial courses should be provided for students who do not have the necessary pre-requisites so they can obtain them prior to admission into the lab.

**Mode of delivery of instruction.** Although the research participants felt that virtual instruction is a very successful instructional delivery mode, they did indicate that the best mode to enhance student learning is the blending of the virtual lab and physical lab. They felt that virtual lab experiences can put students at a higher level of learning once they are in the physical lab. In addition, blending the two labs can be advantageous when there is limited physical lab space and materials. Based on this finding, it is concluded that the best instructional mode of delivery is that of blending the virtual and physical lab experiences.

**Teacher qualifications.** As indicated by the research participants, teacher qualifications are a very important factor in the development and implementation of a virtual lab. A school can have the very best infrastructure, computer hardware, and software and still fail in its effort to use virtual labs. The key component of success is the teacher. The teacher can make or break the use of virtual labs. Teachers they are the ones who set the tone for a successful learning environment. Teachers of virtual labs must be visionary and have the passion to teach in this environment. They must have the technological knowledge and skills that are required to facilitate virtual learning. And, they must be flexible when things go wrong. It is therefore concluded that the hiring of a teacher to teach in a virtual environment be one of the paramount considerations made when developing and implementing a virtual lab. The teachers need to be willing to constantly upgrade their skills on a yearly basis to keep up with technological advances.

### **Discussion**

This research study related to the use of virtual labs in a school setting. In particular, it identified benefits associated with using virtual labs; challenges experienced with developing, implementing, and using virtual labs; solutions that can be used to overcome the challenges; and factors to be considered when developing and implementing virtual labs. A constructivist theoretical framework was chosen because it was in line with the purpose for which virtual labs were used to teach students – making their own interpretations during and after doing the labs. Of all the data obtained from this study, two areas in particular stood out to the researcher as needing further discussion. These two areas include the students who can benefit the most from a virtual learning environment and the notion of blending virtual and physical labs.



## **Students Who Can Benefit the Most from Virtual Labs**

It is interesting to note that most of the participants felt that in order for students to be successful in a virtual lab, they need to meet certain prerequisites prior to participating in the lab. These prerequisites include technological understanding and competence, maturity, and competence in basic academic skills. If students are not proficient in all of these areas, their chances of success are minimal. On the other hand, about half of the participants felt that total inclusion should be followed when deciding who should be allowed to take a virtual lab, even if it meant failure for a given student. The reason given for allowing anyone to take a virtual lab primarily revolved around class enrollment, because if there are not enough students to take the class, then the class will not be offered. For the participants who felt this way, operating by inferior policies only breeds inferior results. These inferior results will have a negative impact on the reputation of the virtual lab and thereby rendering it a course that capable students would not want to take. By having certain prerequisites and enforcing these prerequisites, programs usually excel in enrollment and in assisting students to experience success, not failure. Furthermore, enforcing prerequisites does not mean turning those students away who do not have them. To the contrary, to truly help these students, remedial courses need to be offered to ensure the students will meet the required prerequisites. By having these types of courses, students will be served and teachers will not have to worry about losing their jobs.

According to Chu (1999), in order to be successful, a virtual lab needs to have interactivity so that each concept can be presented to students in form of exercises which in turn challenge the students to solve the problems they encounter while doing their lab. This is also in line with the tenets of constructivism because as students encounter difficulties, they will make sense of them and decide the measure to take in order find solutions.

## **Blending Virtual and Physical Labs**

Although all of the participants felt that virtual labs can, indeed, be beneficial to students, they also pointed out that the most effective way to assist students to learn at their optimal level is to blend the two environments, an argument also supported by Staker & Horn (2012). The research participants thought that by using virtual labs prior to physical labs, students would be at a higher level of learning once they got into the physical lab environment. They also thought that when resources are limited with regard to expensive equipment and materials for physical labs, using virtual labs would reduce the resources needed to operate physical labs. Furthermore, with the ever-increasing number of electronic devices that are available to the public and those that will be introduced, blending virtual instruction with physical labs may be easier than currently thought. Devices such as iPads, iPods, PDAs, and smartphones are being introduced to and used by educational institutions all across the world (Pegrum, Oakley, & Faulkner, 2013). It is not too far-fetched to think that with these new devices and those that are to come, many of the challenges for using virtual labs that were identified in this study may become a thing of the past.

## **Cost-savings Associated With Using Virtual Labs**

Even though the initial phase of developing a virtual laboratory may be expensive (Staker & Horn, 2012), there is bound to be cost savings in the long run. Initially, it is expensive but later the cost goes down. New equipment, usually cheaper, will come in and take up the initial cost of development. This means that when planning the development of such ventures, planners should not be discouraged by the initial cost because they are bound to recoup their expenses after some time. In the case of using dangerous and expensive chemicals, virtual labs prove to be cost-saving because students are not exposed to the dangerous materials (Raman, Nedungadi, Achuthan, & Diwakar, 2011). Therefore, there should not be any kind of discouragement on the

part of individuals or organizations that embark on such a venture. In instances where there are too many students as compared to the available machinery, virtual labs can be used to reduce overcrowding since students will be doing the labs at a location of their convenience.

### **Transferability To Developing Countries and Other Resource-Limited Communities**

Although the settings are not quite the same, the findings of this research can still be transferred to other contexts. In order for the findings of this research to be completely transferable to other contexts, the following considerations need to be made:

- a. Consider the number of people the lab is going to impact;
- b. Train pioneers to start the virtual labs;
- c. Infrastructure must be ready to accommodate the virtual machines;
- d. There has to be adequately qualified teachers;
- e. Ensure that content that is needed to teach is stored on CDs in case there are internet connectivity problems, and;
- f. Secure continuous funding from United Nations, other charitable organizations or individual governments for continuous training and replacement of virtual machines.

### **Recommendations for Practice**

Based on the findings and conclusions of this research study, the following recommendations for practice are presented:

1. Prior to deciding what kind of virtual lab to development and implement, a thorough investigation of the infrastructure should be completed with the assistance of technical specialists. The current infrastructure that is available in a given site needs to be determined and if necessary, an estimate of the cost to upgrade the infrastructure needs to

also be determined. Finally, a five-year budget should be developed to determine the amount of resources needed to maintain the virtual lab.

2. Some CTE program areas do not lend themselves to using virtual labs. Therefore, when considering the use of virtual labs, make sure it is in a CTE program area where this type of learning environment best fits and will ensure student success.
3. There should be careful consideration concerning who will be hired to teach the virtual lab. The teacher should have up-to-date technological knowledge and skills, be a visionary, have passion for teaching in a virtual environment, have up-to-date knowledge and skills related to industry standards in a given field, be a person who can analyze a situation and come up with solutions for problems as they arise, and have a commitment for working with students.
4. Prerequisites for being allowed to take a virtual lab need to be identified and enforced. For students who do not meet these prerequisites, remedial courses should be provided to assist them in obtaining the prerequisites.
5. The model of blending virtual labs with physical labs should be highly considered when determining the best model for enhancing student learning.
6. Plans for teacher training and updating needs to be a part of the budget for operating a virtual lab. Not providing teachers the necessary initial training and continual updating will only lead to eventual failure of the lab.
7. Time should be given to teachers to develop alternative plans of instruction to use when the virtual lab breaks down. Teachers should not be expected to develop these alternative delivery methods on their own time.

8. A formal mechanism for teacher collaboration should be provided. Helping each other learn and solve problems can serve as a positive influence to enhance teacher morale.

### **Recommendations for Further Research**

This study reflected the views of 15 professional educators, all of whom had experiences with using virtual labs. Based on the findings of the study, the researcher makes the following recommendations for further research.

1. A longitudinal study on the success of students in a virtual lab who did not meet the prerequisites for the lab, but who were given remedial courses prior to taking the lab.
2. A longitudinal study to determine the extent to which having and enforcing prerequisites will have a positive or negative impact on the enrollment of a virtual lab.
3. A study comparing the results of offering a virtual lab as a stand-alone course and one that is blended with a physical lab.
4. A study to determine the specific competencies and skills instructors need to possess in order to successfully implement virtual learning technology in their teaching.
5. A study to determine factors related to the use of virtual labs from the perspective of students.

### **Concluding Remarks**

Developing countries across the world are at an impasse with their efforts at moving forward in a global economy. There are so many needs in these countries that it is very difficult to determine where to spend their very limited resources. On the one hand, the resources must be expended to take care of basic human needs, while on the other hand it is important to have resources to catch up with the rest of the world. Being at the same level with the rest of the

world will require being a part of new and ever-changing technological advancements. This alone will take more resources than most developing countries have.

This research study was conducted in the U.S., perhaps the most developed country in the world. The researcher is very grateful to having the opportunity to learn from the experiences of citizens in this developed country. This study could not have been conducted in Zambia because very few, if any, educators have the experience with virtual labs to be able to identify benefits for using them, challenges related to using them, solutions for overcoming the challenges, and considerations for developing and implementing them. The researcher has learned a great deal from this study. The results gleaned from the study will allow him to return to Zambia and provide leadership in its efforts to develop and implement virtual labs. Although the settings are not quite the same, having the prior knowledge gained through this study help the researchers in other parts of the world when trying to move forward with this type of learning medium.

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## Appendices

### Appendix A: Interview Protocol for CTE Administrators

Participant information:

Institution:

**Please describe the CTE virtual labs that are currently being used in your school system.**

**1. Benefits associated with virtual labs:**

- a. What are the major advantages that you see in the use of virtual labs in your programs?
- b. Do you think that the use of virtual labs in CTE programs have helped in your teaching CTE-related skills? If so, how? If not, why not?
- c. What benefits have your teachers experienced when using virtual labs?
- d. When using virtual labs, how has skills transfer been applicable to real life situations?

**2. Challenges associated with developing and implementing a virtual lab:**

- a. From an administrative perspective, what are the challenges you experienced that are associated with developing and implementing a virtual lab?
- b. What challenges have you faced when assisting teachers in developing and implementing virtual labs?
- c. How easy or difficult has it been for your teachers to use virtual labs as a teaching tool?
- d. Would you do anything differently when developing and implementing a new virtual lab? If yes, please describe what you would do.

- e. Have virtual labs achieved the learning goals that were set for using them?
- f. What have you done for programs (if any) that have not effectively utilized virtual labs?

**3. Challenges associated with using virtual labs to teach on a day-to-day basis**

- a. How much of a factor are a teacher's computer literacy skills related to effectively using virtual labs? Please explain.
- b. Has change in computer technology impacted your teachers' capabilities of using virtual labs? Please explain.
- c. Do your teachers use virtual labs because they like using them or simply because they are required to so?

**4. Solutions used to overcome the challenges associated with developing, implementing, and using virtual labs:**

- a. What solutions have you applied to overcome the challenges you experienced that are associated with developing and implementing virtual labs?
- b. What solutions have you applied to assist your teachers in overcoming challenges associated with developing and implementing virtual labs?
- c. What solutions have you used to assist your teachers in overcoming challenges associated with the daily use of virtual labs?

**5. Factors to consider when planning the development, implementation, and utilization of virtual labs:**

- a. What factors should be considered when planning the development and implementation of virtual labs?
- b. What factors should be considered when utilizing virtual labs?

- c. How can virtual labs be best introduced in a learning environment?
- d. Is student selection for purposes of virtual learning something worth considering?  
Please explain.
- e. Do your teachers' and students' abilities match the demands of virtual learning?  
Please explain.
- f. What other comments do you have to share about the implementation and use of virtual learning?

## **Appendix B: Interview Protocol for Teachers/Professors**

Participant information:

Institution:

**Please describe the CTE virtual labs that are currently being used in your school.**

### **1. Benefits associated with virtual labs:**

- a. What are the major advantages that you see in the use of virtual labs in your programs?
- b. Do you think that the use of virtual labs in CTE programs has helped in your teaching CTE-related skills? If so, how? If not, why not?
- c. What benefits have you experienced when using virtual labs?
- d. When using virtual labs, how has skills transfer been applicable to real-life situations?

### **2. Challenges associated with developing and implementing a virtual lab?**

- a. From a teacher's perspective, what are the challenges you experienced that are associated with developing and implementing a virtual lab?
- b. What challenges have you faced when developing and implementing virtual labs?
- c. How easy or difficult has it been for you to use virtual labs as a teaching tool?
- d. Would you do anything differently when developing and implementing a new virtual lab? If yes, please describe what you would do.
- e. Have virtual labs achieved the learning goals that were set for using them?
- f. What have you done for programs (if any) that have not effectively utilized virtual labs?

### **3. Challenges associated with using virtual labs to teach on a day-to-day basis?**

- a. How much of a factor are your computer literacy skills related to effectively using virtual labs? Please explain.
- b. Has change in computer technology impacted your capabilities of using virtual labs? Please explain.
- c. Do you use virtual labs because you like using them or is it simply because you are required to so?

**4. Solutions used to overcome the challenges associated with developing, implementing, and using virtual labs:**

- a. What solutions have you applied to overcome the challenges you experienced that are associated with developing and implementing virtual labs?
- b. What solutions have you applied to overcome challenges associated with developing and implementing virtual labs?
- c. What solutions have you used to assist you overcoming challenges associated with the daily use of virtual labs?

**5. Factors to consider when planning the development, implementation, and utilization of virtual labs:**

- a. What considerations need to be made when planning the development and implementation of virtual labs?
- b. What considerations need to be made when utilizing virtual labs?
- c. How can virtual labs be best introduced in a learning environment?
- d. Is student selection for purposes of virtual learning something worth considering? Please explain.

- e. Do your abilities and those of your students' match the demands of virtual learning? Please explain.
- f. Are there questions that I didn't ask, which I should have asked?



## **Appendix C: Informed Consent**

### **VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY**

#### **INFORMED CONSENT FORM FOR PARTICIPANTS OF INVESTIGATIVE PROJECT**

**Title of Project:** Benefits and Challenges Associated with Using Virtual Labs and Solutions To Overcome Them

**Investigators:** Luka Ngoyi, Ph.D. Candidate, Virginia Tech.

Dr. William T. Price, Advisor, Virginia Tech.

#### **I. Purpose of this Research/Project**

The purpose of this study is to examine your experience with regards to using virtual labs in teaching your students. Together, we will try to understand how teachers and career and technical education (CTE) administrators have been coping with virtual learning and try to understand the kinds of benefits and problems they have been facing and then you will offer solutions to the problems which we will come up with.

#### **II. Procedures**

You are among approximately 20 individuals being invited to participate in this study. By signing this consent form, you are agreeing to participate in an interview with me, which will take between 45 and 60 minutes to complete. During the interview you will be asked several questions about your experience in using virtual labs in some of your lessons.

#### **III. Benefits of Participation**

Your participation in this study will help us better understand and appreciate the benefits, and challenges teachers and CTE administrators face when using virtual labs. The researcher will share with you the findings of this research so that you may know what other teachers have been doing to overcome the problems they have been facing with virtual labs. All in all, your

participation will add to the body of knowledge related to the use of virtual labs in education.

You may leave the interview with a better understanding and appreciation for the problems you have been facing with virtual labs.

#### **IV. Risks of Participation**

There are no known risks to participating in this study.

#### **V. Extent of Anonymity and Confidentiality**

All the information from the interview will be kept strictly confidential. In any written reports you will be identified by a code number or a pseudonym. Any names of people or places that you mention will be changed. The interview recordings will be transcribed verbatim and will be kept in a locked filing cabinet when they are not being used for transcription or analyses. The information that is provided during the interview process will be kept confidential and used for research purposes only. After all of the interviews are conducted, data is recorded, and my dissertation is successfully defended, all the recordings will be destroyed.

#### **VI. Compensation**

You will not receive any monetary compensation for participating in this interview.

#### **VII. Freedom to Withdraw**

Participation in this study is voluntary. If there is a question that you feel uncomfortable answering, you have the right to skip it and continue on with the interview. In addition, you have the right to terminate the interview at any time without any type of penalty.

#### **VIII. Approval of Research**

This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University.

#### **IX. Subject's Responsibilities**

I voluntarily agree to participate in this study. My responsibilities include answering interview questions.

### **X. Subject's Approval**

I have read and understood the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent for participation in this project. If I choose to participate in this research study, I may withdraw at any time without penalty. I agree to abide by the procedures of this study.

---

Signature Date

Should I have any questions about this research or its conduct, I may contact:

Luka Ngoyi – Investigator 540-818-9673

Dr. William T. Price– Investigator's Advisor 540-818-6894

Dr. H.T. Hurd– Chair, Institutional Review Board 540-231-5281

Research Division, Virginia Tech

## **Appendix D: Sample E-mail to CTE Administrators**

Dear. XXXX

I am a doctoral student at Virginia Polytechnic Institute and State University (Virginia Tech.) engaged in research for the purpose of satisfying a requirement for a Doctor of Education degree. You have been identified because of your experience in using and administering the use of virtual programs in your school.

The intent of this letter is to ask you to participate in this research by way of answering interview questions.

The purpose of this study is to examine your experience with regards to using virtual labs in teaching your students. Together, we will try to understand how teachers and career and technical education (CTE) administrators have been coping with virtual learning and try to understand the kinds of benefits and challenges they have been facing and then you will offer solutions to the challenges which we will come up with in this interview.

If you agree to participate, you will be asked to participate in an interview session. The interview will help to identify the benefits, challenges and solutions associated with the use of virtual labs in your school.

The data from this research will be used to identify the types of benefits, challenges and solutions needed by Zambian career and technical education (CTE) administrators to establish guidelines for selecting, using and implementing virtual labs.

The questionnaire will take approximately 40-60 minutes to complete.

I am also writing to ask whether you would be willing to pass along this information to your teachers, colleagues, friends and other members who may also be interested in participating in this research study. If you are willing to help in identifying the teachers suitable for this study,

then, at a minimum, the following is the criteria I will use to identify the teachers: (a) they must have been using virtual labs at least twice a week or one grading period; (b) they must have had more than a year's experience in using virtual labs; (c) they must have been consistent with the use of the virtual labs in their classrooms; (d) they must have been actively serving as teachers; and (e) the type of virtual labs they used was not of importance in this research.

Thank you in advance.

Sincerely yours,

Luka Ngoyi

## **Appendix E: Sample E-mail to CTE Teachers**

Dear XXXX,

I am a doctoral student at Virginia Polytechnic Institute and State University (Virginia Tech.) engaged in research for the purpose of satisfying a requirement for a Doctor of Education degree. I received your name from Dr. XXXX. You have been identified because of your experience in using and administering the use of virtual programs in your school. The intent of this letter is to ask you to participate in this research by way of answering interview questions. The purpose of this study is to examine your experience with regards to using virtual labs in teaching your students. Together, we will try to understand how teachers and career and technical education (CTE) administrators have been coping with virtual learning and try to understand the kinds of benefits and challenges they have been facing and then you will offer solutions to the challenges which we will come up with in this interview.

If you agree to participate, you will be asked to participate in an interview session. The interview will help to identify the benefits, challenges and solutions associated with the use of virtual labs in your school. The data from this research will be used to identify the types of benefits, challenges and solutions needed by Zambian career and technical education (CTE) administrators to establish guidelines for selecting, using and implementing virtual labs. The questionnaire will take approximately 40-60 minutes to complete.

Thank you in advance.

Sincerely yours,

Luka Ngoyi