

بسم الله الرحمن الرحيم
Sudan University of Science and Technology
College of Graduate Studies

**Implementation of Virtual Laboratories in Teaching Practical General Chemistry: An
Experimental Study at Sudan University of Science and Technology**

توظيف المعامل الافتراضية في تدريس عملى الكيمياء العامة :دراسة تجريبية بجامعة السودان للعلوم
والتكنولوجيا

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Initiation

إستهلال

قال الله تعالى:

بسم الله الرحمن الرحيم

(.....نَرْفَعُ دَرَجَاتٍ مَّنْ نَّشَاءُ وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ) الآية

(٧٦)

سورة يوسف

Dedication

To my Mother

She was my friend in her life

After her death became my conscience

Huda

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I would like to thank:

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مستخلص الدراسة:

المختبر الافتراضي هو أحد مستحدثات تكنولوجيا الواقع الافتراضي ، وقد أثبتت عديد من الدراسات فاعلية استخدامه في العملية التعليمية. ويهدف هذا البحث إلى توضيح الأثر الذي يحدثه توظيف أحد تطبيقات التعليم الإلكتروني (المختبرات الافتراضية) في تدريس عملي الكيمياء العامة لطلاب المستوى الأول بجامعة السودان للعلوم والتكنولوجيا، ويقوم التطبيق على محاكاة تعليمية تفاعلية للمختبر التقليدي . ومن ثم معرفة اتجاهات الطلاب والأساتذة نحو استخدام المختبر الافتراضي في العملية التعليمية.

وقد أجري البحث باستخدام المختبر الافتراضي كروكودايل كلبس ، يشمل البحث جزءاً مختاراً من تجارب الكيمياء العامة العملية و تسمى تفاعلات التعادل (الأحماض مع القواعد). وفي هذا المعمل الافتراضي يجد الطالب كل ما يحتاج من مواد كيميائية وأدوات زجاجية ومعدات أخرى لأجراء التجارب، وتبدو المحاكاة وكأنها حقيقية من حيث إجراء التجارب وتغير الألوان. وتحتوي المعامل الافتراضية على أدوات تدعم التجربة مثل مسار التفاعل والرسم البياني، ومشاهدة بنية الجزيئات بشكل ثلاثي الأبعاد وكذلك الاطلاع على المعادلات الكيميائية في صورها الثلاث (أيونية، لفظية ورمزية). كما تناولت الورقة مفهوم المعامل الافتراضية وتوضيح علاقتها بالتعليم الإلكتروني، وذكر لأهم مميزات إستخدامها وعيوبها، مع الإشارة الى المكونات الرئيسية للمعامل الافتراضية و لبعض الدراسات السابقة الرائدة في مجال استخدام المعامل الافتراضية وإبراز لأهم نتائج الدراسات في هذا المجال.

ثم صممت استبانات، لمعرفة اتجاهات الطلاب والأساتذة نحو استخدام المختبر الافتراضي في تدريس الجانب العملي للكيمياء العامة. وقد تكونت عينة الدراسة من مجموعتين : ضمت (144) طالبا وطالبة ، وقد تم الاعتماد على المنهج التجريبي كمنهج قامت عليه الدراسة.

ومع عدم وجود فروق واضحة في تحصيل الطلاب الأكاديمي، توصلت البحث الى أن استخدام المختبر الافتراضي ساعد الطلاب على التعامل مع التكنولوجيا الحديثة والتعرف على مميزاتاها و عيوبها ، وكذلك ساعد الطلاب على إكتساب مهارات التجارب المعملية ، مما أدى الى تكوين اتجاه إيجابي نحو المختبر الافتراضي. كما ساعد استخدام المختبر الافتراضي على الشعور بالثقة أثناء استخدام التجارب ، وعلى توفير الوقت للطلاب والأساتذة، مما ساعد الطلاب على تكرار التجربة دون الخوف من استهلاك المواد الكيميائية أو إتلاف المعدات والأواني الزجاجية. بالإضافة لتوفير بيئة تعليمية تعاونية.

Abstract

Virtual laboratories are an application virtual reality technology which its positive impact on learning has been reported in many contemporary studies.

This study reports the results of a study which examined the influence of implementing one of the applications of virtual laboratories in teaching the general practical chemistry course for the first level students of Sudan University of Science and Technology (SUST). The application is an Educational interactive simulation of the traditional laboratory. The study reports the attitudes of the lectures and the students towards the use of the virtual laboratory in teaching. The study was conducted using a virtual laboratory product called "Crocodile Clips". A group of chemistry experiments was selected from the neutralization experiments (acids and bases). In the virtual laboratory the students found all requirements including chemical reagents, glassware and other apparatus needed for conducting an Experiment.

The chemistry experiment looked like real as far as the processes and colours. The virtual laboratory system consisted of tools for supporting the Experiment such as displaying the progress of the reaction, graphs and the observation of the structure of Molecules in 3D as well as displaying chemical equations in their forms (ionic, verbal and symbolic).

The study also discusses the concept of virtual laboratories and its relationship to e-learning mentioning the pros and cons of their use followed by a brief survey of the research contributions in this area.

A questionnaire was designed to find the attitudes of students and lectures towards the use of virtual laboratories in general practical chemistry. A sample consisting of (144) students were used.

The study found that the use of the virtual laboratories gave the students the opportunity to interact with modern technology discovering its pros and cons. It assisted the students to become skilful in conducting laboratory experiments thus creating a positive attitude towards virtual laboratories. However, no significant difference was observed between the performances of the students using traditional and virtual laboratories. The virtual laboratories gave the Students a feeling of confidence when conducting the real experiments. It led to conserving the time of students and lectures and they could repeat experiments without the worry of consuming chemicals or damaging equipment or glassware. Over and above, it has created a cooperative educational structure.

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Chapter One

Introduction

1.1 Introduction

The purpose of this study is to assess the effectiveness of implementing virtual laboratory in the teaching of the practical general chemistry curriculum at the Sudan University of Science and Technology (SUST).

Radical changes have occurred in the world due to innovations in information and communication technology (ICT). Both the Sudanese people and the educational curricula have to cope and keep abreast with changes, innovations and developments. Direct observations emerged due to ones experience as a researcher and lecturer at the Sudan University of Science and Technology. Passing through the various secondary schools for educational supervision it to appear that the education process, in developing countries faces the problem that large numbers of students are accommodated in classrooms. However, there are individual differences among learners and this makes it difficult for the teacher to address the manner in which each learner learns. Here it is evident the role of technology, which allows multiple types of stimuli and learning, reduces the gap between individual learners. This chapter starts with a brief general introduction, followed by a background. Next, the rationale, and the statement of the research problem will be discussed – with the purpose and specific objectives of the study. Subsequently, the research questions and the theoretical perspective will be explored. Then, the definition of terms as well as the evaluation of research will be covered. The research population, participants and conceptual framework will be covered next. Research design and methods will then be described followed by the limitations of the study.

1.2 Background

Sudan is now addressing previous generation's problems. Therefore, care should be directed towards the establishment of different layers of education, e.g. at pre-primary education, primary, secondary and university educational levels and illiteracy eradication shoring. These establishments are created by society to construct the generations according to society's goals. These goals may differ from one society to the next. In this regard, Hamdy (2007) proclaims that:

“In June 1999, the Sudanese national ICT strategy was formulated and a high-level ministerial committee was formed to oversee its implementation. The strategy focuses on five major areas: technology (infrastructure), human resource development, software industry development, content (Arabic reservoir), and geo-information”

The policy continued by stating that the General Ministry of Education is responsible for the development of a strong ICT infrastructure as well as the development of e-learning in Sudan. “The national policy encourages the use of ICT in developing local policies to ensure the complete integration of ICT in education and training on all levels.” (Hamdy, 2007)

1.3 Rationale

The importance of this study is to understand the requirements and obstacles of the implementation of virtual laboratory at a Sudanese university, with particular concentration on the Sudan University of Science and Technology. It is, amongst others, necessary to determine the approaches, constraints, fit for purpose, required interface, necessary infrastructure, and readiness of university professors and students to participate effectively in virtual laboratory. This study also takes into consideration the input from policy level on higher education to assist in the use ICTs in higher education. Also, the wider community may also become more aware of the importance of using ICTs in its contribution towards decreasing the cost of education and training at higher education institutions and its involvement with higher education.

1.4 Problem statement

Practical chemistry laboratory training is still regarded as one of the most important means of training students in chemistry. Traditionally, practical chemistry have, over many years, assisted students to achieve educational objectives and learning outcomes.

The research problem came through the researcher's observations when she was the controller of the chemical laboratories at the college of Education, in Sudan University of Science and Technology (SUST). The problem noted was that many errors and accidents occurred during simple laboratory tests and experiments in laboratory practical sessions. Therefore, it was proposed that of virtual laboratory may improve and enhance the performance of students in practical chemistry. They many subsequently achieve practical-chemistry skills and learning outcomes.

1.5 Purpose of the research

The purpose of this study is to test the possibility of implementation virtual laboratory for the teaching and learning of the general practical chemistry curriculum at the Sudan University of Science and Technology (SUST).

1.6 The Research objectives

The objectives of the research are to:

1. Identify the effectiveness of virtual laboratories for teaching practical general chemistry.
2. Identify the readiness of students and lecturers at Sudan University of Science and technology to implement and integrate virtual laboratories in practical general chemistry.
3. Explore the readiness of Sudan University of Science and technology for the implementation of virtual laboratories for teaching practical general chemistry in terms of infrastructures and human resources.
4. Address the obstacles that prevent Sudan University of Science and technology Students from implementing virtual laboratories in general practical chemistry.
5. Suggest and provide some solutions to address and overcome these obstacles.

1.7 Research questions

The main question of this research is:

How should virtual laboratory be adopted in teaching and learning of practical general chemistry at the Sudan University of Science and Technology to help both lecturers and students in learning?

The sub questions are:

1. To what extent can virtual laboratories improve the process of teaching and learning practical chemistry?
2. To what extent students and lectures at Sudan University of Science and technology are ready to implement virtual laboratories to attain learning objectives?
3. How Sudan University of Science and technology is equipped for the implementation of virtual laboratories for teaching practical general chemistry in terms of infrastructures and human resources?
4. What obstacles are facing the Sudan University of Science and technology to implementing virtual laboratories in teaching practical general chemistry?
5. How Sudan University of Science and technology can addresses and overcomes these obstacles?

1.8 Theoretical perspective

A widely used methodology for developing new training programs is instructional design (ID). Related and adjacent fields of learning concerned with improving of instruction are Instructional Systems Design (ISD), Instructional Systems Design and Development (ISDD), and the Systems Approach to Training (SAT). These approaches provide step-by-step systematically approaches to the evaluation of students' needs, the design and development of training materials, and the evaluation of the effectiveness of the training intervention (Kruse, 2002).

Chou's (2000) work provides an instructional design framework to simultaneously facilitate teaching and learning activities. It also provides an interdisciplinary framework that relates to desirable learning outcomes and plays a critical role in the success of distance education. Furthermore, it also provides a theoretical background for the design and implementation of instructional units for the achievement of learning outcomes. It is also encompasses design principles and theories for learning and teaching. This study is based on a theory that is

interested in using technology in education in order to assess the effectiveness of the use of technology in teaching and learning, the activity theory (2000, 2009).

Forbes, Madeira, Davis, and Slotta (2009), teachers play a key role in facilitating and enhancing the learning process for students. Teachers should pursue develop and build new knowledge to become a more effective in the education process.

According to Learning Theories Knowledgebase (2009), Activity Theory is a descriptive meta-theory or framework, rather than a predictive theory. It considers the entire work/activity system beyond just one actor or user. It accounts for the environment, history of the person, culture, role of the artifact, motivations, and complexity of real life action. The unit of analysis is motivated activity directed at an object (goal). It therefore also includes cultural and technical mediation of human activity, as well as artifacts in use (and not in isolation) in the system. Activities consist of goal-directed actions that are conscious. Constituents of activity are not fixed; they can dynamically change.

There are three levels of activity:

- “Activity towards an objective (goal) carried out by a community. A result of a motive (need) that may not be conscious social and personal meaning of activity”. This will address the question relating to the “Why?” question.
- “Action towards a specific goal (conscious), carried out by an individual or a group possible goals and sub goals, critical goals”. This will address the “What?” question.
- “Operation structure of activity typically automated and not conscious concrete way of executing an action in accordance with the specific conditions surrounding the goal”. This will address the “How?” question.

Activity theory is associated with the implementation and assessment of the efficiency and effectiveness of technology in education. It's important concepts: it looks at the social and cultural entrance .It helps to shape the cultural aspects provide the climate for human growth and learning. Chemistry in particular is an interesting application. The "cultural activities" theory of Engeström (1987, 1999) will be adopted in order to understand the role of technology in achieving activities, and to help in assessing the educational process.

1.9 Definition of terms

E- Learning: “E-learning most often means an approach to facilitate and enhance learning by means of personal computers, CD-ROMs, audio visual aids and the Internet” (Shinde and Jadhav, 2005).

Virtual Laboratory: “Is an interactive virtual space that incorporates all the technological, pedagogic and human resources in order to perform practical activities, adapted to the student and teacher’s needs in a virtual learning environment”. (Prieto, et al, 2008)

Information and Communication Technology: “ICT is defined as the combination of informatics technology with other, related technologies, specifically communication technology” (UNESCO, 2002).

1.10 Evaluation research:

In this study, both qualitative and quantitative methods will be used to collect data from the selected sample. These methods will aid in building a base on a complete understanding of the research problem. Qualitative research is a multi-method approach to the study of social interactions in natural settings. It involves the collection and analysis of empirical data from multiple sources such as field observations, semi-structured and open-ended interviews, oral histories, visual records, and focus groups, among others (Patterson, 2004). Qualitative research follows from a poststructuralist paradigm. There are five areas of qualitative research: case study, ethnography study, phenomenological study, grounded theory study, and content analysis. These five areas are representative of research that is built upon inductive reasoning and associated methodologies (Williams, 2007).

“Quantitative researchers seek explanations and predictions that will generate to other persons and places” (Williams, 2007). Quantitative research also involves data collection that is typically numeric and the researcher tends to use mathematical models as the methodology of data analysis. Additionally, the researcher uses the inquiry methods to ensure alignment with statistical data collection methodology (Williams, 2007). According to Williams (2007), there are three broad classifications of quantitative research: descriptive, experimental and causal comparative (Leedy and Ormrod, 2001). The descriptive research approach is a basic research method that examines the situation, as it exists in its current state. Descriptive

research involves identification of attributes of a particular phenomenon based on an observational basis, or the exploration of correlation between two or more phenomena.

1.10.1 Research design

Research design refers to the plan for selecting subjects, research sites, and data collection procedures to answer the research question(s). The design shows which individuals will be studied, and when, where and under which circumstances they will be studied (McMillan & Schumacher, 2001).

Design research is not an activity that an individual researcher can conduct in isolation from practice; progress will be made with respect to, at the very least, clarification of its very nature ensures that problems facing lecturers and learners. Ideally, it is the creation and adoption of solutions in tandem with the elucidation of robust design models and principles. (Reeves, 2006)

The researcher depended on the experimental method (group rotate) for its suitability with the research goal, as the aim of this research is to use two methods, of teaching; the traditional laboratory and the virtual laboratory approach. For the first group the first variable is tested, for the second group the second variable is tested, then after a time the second variable is tested by the first group and the first variable is tested by the second group.

1.10.2 Research population and participants

The population of this study will be the Sudan University of Science and Technology. The participants will be lectures, first year student from two colleges, deans, and heads of departments at the various colleges as well as technicians in the laboratory. The choice colleges are according to the large number of students and also the infrastructure of these faculties (equipment, furniture). Thus the Faculties of Medical Laboratories and Education were chosen. In addition scientific researcher will be regarded as stakeholders for this study.

1.10.3 Data collection instruments

Table 1.1: Research matrix and data collection

Research question	Data collection methods				Data collection Strategies						
	Questionnaire	Observation	Interview	Experimental method	Teacher questionnaire	Students questionnaire	Technicians interview	Deans, Head of department interview	Interested in e-learning interview	Researcher Observation	Experimental method
To what extent can virtual laboratories improve the process of teaching and learning practical chemistry?	✓	✓		✓		✓				✓	✓
To what extent students and lectures at Sudan University of Science and technology are ready to implement virtual laboratories to attain learning objectives?	✓		✓		✓		✓	✓			
How Sudan University of Science and technology is equipped for the implementation of virtual laboratories for teaching practical general chemistry in terms of infrastructures and human resources?	✓	✓	✓		✓	✓	✓	✓			
What obstacles are facing the Sudan University of Science and technology to implementing virtual laboratories in teaching practical general chemistry?			✓		✓			✓	✓		
How Sudan University of Science and technology can addresses and overcomes these obstacles?			✓					✓	✓		

1.10.4 Sample population for each methodology

Observation of 144 students from two colleges will be used; interviews will be conducted with deans and heads of departments in the stated colleges, questionnaires to lecturers and Students. An experimental method with students will be use (see Table 1.2 below):

Table 1.2: Experimental method

Group name	The Number of Students	The Independent variable	The dependent variable	Experimental Method
Group(A)	(69) Students from first year faculties of education and Medical Laboratories from the Sudan University of Science and Technology were randomly selected.	Teaching using technology (virtual laboratories) <i>before</i> using traditional method (traditional laboratory)	Academic achievement (recall, comprehension). Skills approach to problem solve	The students wrote the report after their study the virtual laboratory Objective measurement of the increase in knowledge and teaching skills in the use of technology (virtual laboratories) in teaching science.
Group (B)	(75) Students from first year faculties of education and Medical Laboratories from the Sudan University of Science and	Teaching using traditional method (TL) <i>before</i> Using technology(VL)	Academic achievement (recall, comprehension). Skills approach to	The students wrote the report, after their study the traditional

	Technology were randomly selected.		solve the problem	manner Target work compared to see any teaching methods (traditional - Technology) helped to teach science in a better way
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1.11 Data analysis procedures

Quantitative data from the questionnaires and students' reports were analyzed by SPSS program. Qualitative data (collect by interview and observation) were analyzed manually.

1.12 Significance of the study

E-Learning has become a core component of the educational process, with increased interest in e-learning due to the progress of information and communication technology. The emergence of the Internet and technology in the field of learning has also played a part. Many countries are trying to take advantage of e-learning and educational technology to improve learning. It also gives motivation to the lecturers and learners to keep abreast of progress and continuing evolution in technology and science. E-learning is learning in ways that suit the characteristics of learners and the methods of exciting and enjoyable.

The e-learning afford solutions for many problems facing education, such as:

1. Insufficient academic skills and the scarcity of lecturers and increase in the number of students.
2. Interest in the process of instruction until the beginning of the calendar with the benefit of a large feedback at all times.
3. Influences of the barriers of time and space.
4. Solving the problems of testing hazardous or costly and complex.

5. Influence on practice and application.

The importance of this research resides on the above argument and the continual development of the technology, and its role in education.

1.13 Delimitations of the study

This study concerns the Sudan University of Science and Technology for the Integration of virtual laboratory in practical general chemistry. In order to duration centre and to ensure validity, some issues should be considered:

- Time of study: 2010- 2013.
- Location of study: Khartoum, Sudan.

1.14 Conceptual framework

The conceptual framework used in this research to is clarify the possible courses of action or to provide the preferred approach to the idea, it can act like maps that give coherence to empirical inquiry. (Wikipedia, 2011, web page)

1.14.1 The areas of knowledge

There are *three areas* of knowledge: content, pedagogy, and technology.

1. Content (C): is the subject matter that is to be learned or taught.
2. Technology (T): encompasses modern technologies such as computers, the Internet, digital video and more commonplace technologies including overhead projectors, blackboards, and books
3. Pedagogy (P): describes the collected practices, processes, strategies, procedures, and methods of teaching and learning. It also includes knowledge about the aims of instruction, assessment, and student learning. (Koehler & Mishra, 2005, P133)

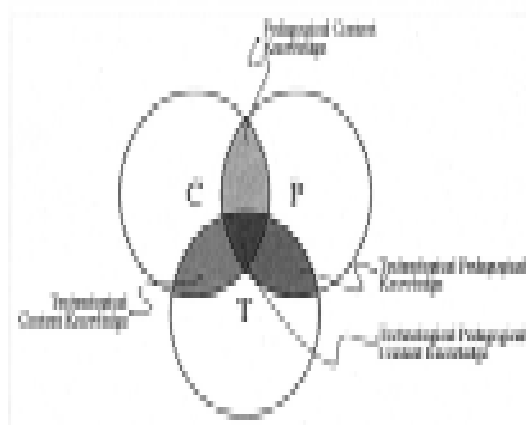


Figure: 1.1. The components of technological pedagogical content knowledge (Koehler & Mishra, 2005)

In this study the technology content of scientific knowledge is used to teach general chemistry (the practical part), where the right technology (Hardware and Software), is used in a specific environment (chemical laboratories and computer labs) at the Sudan University of Science and Technology.

1.14.2 Chemistry education

“Chemistry is not only a basic or pure science subject, but it has a fan of important applications in various industries and in biotechnological and environmental matters” (Donoso, Ortega-Castro, Vilanova, Frau, & Muñoz, 2010, P, 762).

1.14.3 Information and Communication Technologies (ICTs)

“Information and Communication Technologies (ICT) consists of computer hardware, software, Internet and other communication networks, and media used to collect, store, process and transmit information in the form of voice, text, data and images.” (Prasad and Sreedevi, 2007, P. 107)

ICT consist of the hardware, software, networks, and media for collection, storage, processing, transmission and presentation of information (voice, data, text, images), as well as related services. (Word Bank Group, 2002, P, 3)

1.14.4 Role of ICT in the curriculum

The role for ICT in the curriculum includes:

1. Learning about ICT: ICT as a subject of learning in the school curriculum, such as computer literacy, computer sciences and information literacy.
2. Learning with ICT: The use of various computer capabilities such as computation multimedia, internet or World Wide Web (WWW) as a medium to enhance instruction or as a replacement for other media without changing beliefs about the approach to and the methods of teaching and learning.
3. Learning through ICT: Here ICT is integrated so completely as essential tool in a course/curriculum that the teaching and learning of that course/curriculum is no longer possible without it. (Kainth & Kaur, 2009) This study focused on this learning role, by focusing on learning and teaching through ICT.

1.14.5 E -learning system

E-learning is a way of teaching by using the communication devices of modern computers and networks, and multimedia of sound and picture, graphics, and electronic libraries, as well as Internet portals, whether remotely or in the classroom. The intention is to use technology of all kinds to deliver information to the learner. This will be the most direct, consume less time and effort and provide greater utility. (Al Moosa, 2003)

E-learning does not defeat the role of the teacher; instead their role becomes more important and more difficult, because it is one of the basic components. Therefore, it needs the ability to teach and use modern teaching techniques, including the Internet and E-mail. (UNESCO, 2008)

The role of universities in the use of ICT in higher education is becoming increasingly important for the deployment of e-learning and transfer of knowledge for lecturers, students and researchers. Also, the movement of learning environments with e-learning applications is of critical importance for the future of peace in the world. (Varis, 2005)

This study is investigating the possibility of using virtual laboratory in teaching practical chemistry to first year students (study conducted in the Sudan University of Science and Technology).

1.14.6 The Theory and practice of ICT in education

According to Abdel Ati (2010), the role of ICT at higher education is to enrich online courses and learning materials with interactive multimedia. Technology is a significant factor in all the different stages of education to improve the teaching and learning processes. However, the integration of technology in higher education specifically, is of critical importance. (OECD, 2005)

The conceptual framework in this research presents the need to develop an understanding of students, lecturers and those interested in the educational process in general and higher education, with particular focus on the importance of using new teaching methods to improves students' study.

1.15 Chapter overview

The study was divided into five chapters as shown in table 1.2. Below:

Table 1.3: chapter overview

Chapter	Title
Chapter one	Introduction
Chapter two	Overview of previous studies and theoretical framework
Chapter three	Research design and methodology
Chapter four	Data presentation, analysis and discussion of e- learning integration at the Sudan University of Science and Technology
Chapter five	Summary of the findings, conclusions and recommendations