



# An Activity Systems View of Learning Programming Skills in a Virtual Lab: A Case of University of Jos, Nigeria.

By

GOGWIM, Joel Godwin  
**GGWJOE001**

A minor dissertation submitted in partial fulfillment of the requirements for the award of  
the degree of  
Master of Philosophy in Information and Communication Technologies

in the

Faculty of Humanities  
University of Cape Town  
2017

Supervisor: **Professor Dick Ng'ambi**

## **Declaration**

This research work has not been submitted in whole or part, for the award of any degree. It is my own original work. Each significant contribution to, and quotation in this dissertation from the work, or works, of other researchers has been credited, cited and referenced.

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

---

**DECLARATION**

I, *GOGWIM, Joel Godwin*, hereby declare that the research work on which this dissertation is based on is my original work with the exception where acknowledgements denote otherwise, and that neither the entire research work nor any part of it has been, is being, or is to be submitted for another degree in University of Cape Town or any other university.

I permit the university to reproduce for the purpose of research either the whole or any portion of the research contents in any manner whatsoever.

Signature: .....

Date: .....

## **Abstract**

It is difficult to learn professional courses such as Computer Science without hands-on activities with appropriate technical support. Computer Science programming courses are the core of a Computer Science qualification and some of the learning outcomes of a Computer Science programming course are writing program code, program testing and debugging. Inadequate computers in the computer laboratory and policies that restrict the concept of ‘Bring Your Own Technology’ (BYOT) inside the computer laboratory posed a challenge to hands-on programming activities. However, students in the Computer Science department at the University of Jos learn computer-coding theory, but unable to have hands-on experience due to several reasons.

This research investigates how use of virtual lab on Moodle Learning Management System (LMS) could enhance students’ acquisition of Java programming skills. The virtual lab provides a lab environment for students to practice programming and experiment concepts learned.

Activity Theory was used as a theoretical framework to analyse the activity of Java programming on the virtual lab. Seven participants including the lecturer were enrolled on the Java Programming Language virtual lab practical sessions for this research work. The research activity system focuses on Java hands-on programming tasks for a period of three weeks and after that data was collected using interview and content generated from the virtual lab activities’ chats and forum. Interview questions were developed and administered to students, while a semi-structured interview with the lecturer was conducted.

The data collected from the interviews and the contents collated from chats and forum activities were coded using ICT data analysis tool Nvivo, based on thematic analysis. The data was thoroughly reviewed, explained, interpreted, and analysed using the theoretical framework, activity theory.

The results show that the virtual lab helped students perform practical programming activities, where students accessed and used the virtual lab concurrently at any time and place. The participants used their private computers, mobile devices in the hostels, at home, or at hotspots to access the virtual lab. However, accessing the virtual lab required adequate Internet connection.

The virtual lab programming activity system promoted student-centred learning, self-paced practice, and enabled students to repeat or revisit incorrect assignments multiple times. The activity system's subject (lecturer, students) interacts with the mediating tools (mobile devices, virtual lab) to perform the object (Java programming), which enhanced the achievement of the outcome (programming skills). Therefore, it can be said that the virtual lab mediated hands-on programming activities.

**Keywords:** Virtual lab, Moodle, LMS, mediation, hands-on, program coding, debugging, program testing, eLearning, programming language.

## **Acknowledgements**

It is a privilege and a great pleasure to specially thank Carnegie Mellon Foundation of America and the University of Cape Town, Centre for Educational Technology (CET) in particular for granting me this rare scholarship award and opportunity to study at UCT.

I would like to express my profound gratitude and appreciation to my thesis supervisor Prof. Dick Ng'ambi, for his guidance, thorough feedbacks, support and encouragement throughout the study.

Also, I would like to express my reflective gratitude and indebtedness to Prof. Cheryl Hodgkinson-Williams and Prof. Cheryl Brown for their valuable suggestions, comments, assistance, feedback and encouragement throughout the study.

I owe Prof. Cheryl Brown a big thank you for making my visa acquisition a success at the 'eleventh-hour' after a vigorous struggle at the South African Embassy in Abuja, Nigeria. Your intervention then with the visa process marked the begging of my success towards this study.

Ms Wilma Adams, I appreciate your tireless efforts in providing friction-free administrative logistics throughout our period of study even at odd moments.

To my classmates, I value you all for the collaborative and openly shared experiences and knowledge during our class contact moments; and most importantly the constructive and positive criticisms we offered to each other especially during our presentations.

To my family, I thank you for supports, best wishes, and encouragements.

I say thank you all!

## **Dedication**

I dedicate this dissertation to Carnegie Mellon Foundation of America in partnership with the University of Cape Town and the CET team of wonderful and academic experts who devote their time and energy to change and shape our technology-driven generation through quality contemporary education.

# Table of Contents

<b>Abstract .....</b>	<b>iii</b>
<b>Acknowledgements.....</b>	<b>v</b>
<b>Dedication.....</b>	<b>vi</b>
<b>CHAPTER 1: INTRODUCTION AND BACKGROUND.....</b>	<b>1</b>
<b>1.1 Introduction to the Chapter.....</b>	<b>1</b>
<b>1.2 Background .....</b>	<b>1</b>
<b>1.3 Research Problem Statement .....</b>	<b>6</b>
<b>1.4 Research Question.....</b>	<b>7</b>
<b>1.5 Research Objectives.....</b>	<b>8</b>
<b>1.6 Purpose of the Study.....</b>	<b>9</b>
<b>1.7 Definitions of Concepts and Terms .....</b>	<b>9</b>
1.7.1 Learning Management System (LMS).....	9
1.7.2 eLearning .....	9
1.7.3 Virtual Laboratory (Virtual Lab) .....	10
1.7.4 Programming Language.....	10
1.7.5 Java Programming Language .....	10
1.7.6 Mediation .....	11
<b>1.8 Chapter Summary.....</b>	<b>11</b>
<b>1.9 Thesis Structure.....</b>	<b>11</b>
<b>2 CHAPTER 2: LITERATURE REVIEW.....</b>	<b>13</b>
<b>2.1 Introduction to the Chapter.....</b>	<b>13</b>
<b>2.2 Virtual Lab Overview .....</b>	<b>13</b>
<b>2.3 Virtual Lab Concepts and Empirical Research Review .....</b>	<b>14</b>
2.3.1 Virtual Lab Affordances .....	18
2.3.2 Teaching and Learning Practices in a Virtual Lab.....	21
2.3.3 Virtual Lab Development Tools.....	23
<b>2.4 The Activity Theory.....</b>	<b>25</b>
2.4.1 Cultural-Historical Activity Theory (CHAT).....	29
2.4.2 Review of Related Literature .....	33
<b>2.5 Conceptual Framework of the Virtual Lab Activity System Environment .....</b>	<b>34</b>
<b>2.6 Chapter Summary.....</b>	<b>37</b>
<b>3 CHAPTER 3: METHODOLOGY .....</b>	<b>39</b>
<b>3.1 Introduction to the Chapter.....</b>	<b>39</b>
<b>3.2 The Research Design .....</b>	<b>39</b>
3.2.1 Qualitative Research Methodology .....	39
3.2.2 Descriptive Research Methodology .....	40
<b>3.3 Case Study Selection.....</b>	<b>40</b>
<b>3.4 Data Collection Methods and Instruments.....</b>	<b>41</b>
3.4.1 Interviews.....	42
3.4.2 Content Analysis .....	42
<b>3.5 Data Analysis Technique .....</b>	<b>43</b>
3.5.1 Thematic Analysis.....	43
3.5.2 Data Analysis Tools .....	44
<b>3.6 Research Ethics.....</b>	<b>45</b>
3.6.1 Code of Ethics .....	46

3.6.2	Validity .....	47
3.7	Chapter Summary.....	48
<b>4</b>	<b>CHAPTER 4: RESEARCH FINDINGS AND RESULTS DISCUSSION .....</b>	<b>49</b>
4.1	Introduction to the Chapter.....	49
4.2	Presentation of Data .....	49
4.2.1	Students Interview.....	49
4.2.2	Lecturer Interview.....	51
4.2.3	Virtual Lab Activities' Contents Generated.....	53
4.3	Data Analysis.....	55
4.3.1	Analysis of Interviews.....	56
4.3.2	Analysis of the Activity System Contents Generated.....	81
4.4	Results Discussion .....	104
4.4.1	Interview Results.....	104
4.4.2	Activity System Contents Results.....	111
4.5	Chapter Summary.....	116
<b>5</b>	<b>CHAPTER 5: SUMMARY AND RECOMMENDATIONS .....</b>	<b>118</b>
5.1	Introduction to the Chapter.....	118
5.2	Review of Research Questions.....	118
5.2.1	What is the objective of the virtual lab programming? .....	119
5.2.2	How does the virtual lab programming mediate students' programming skills acquisition?.....	120
5.2.3	What are the teaching and learning practice evident in the virtual lab? .....	121
5.3	Conclusion.....	123
5.4	Recommendations for Further Research.....	124
5.4.1	Further Research.....	125
5.4.2	Recommendations.....	125
	<b>References .....</b>	<b>130</b>
	<b>Appendices .....</b>	<b>145</b>
	<b>Appendix A: Snapshots of Students' Work &amp; Submissions .....</b>	<b>145</b>
	<b>Appendix B: How Lecturer Assigned Tasks in Virtual Lab.....</b>	<b>149</b>
	<b>Appendix C: Visual Relationship Between LMS and Virtual Lab .....</b>	<b>152</b>
	<b>Appendix D: Snapshots of Students Interview Transcription from Nvivo and Text Extracts.....</b>	<b>153</b>
	<b>Appendix E: Snapshot of Lecturer Interview Transcription from Nvivo and Text Extracts.....</b>	<b>158</b>
	<b>Appendix F: Snapshots of Chats Content.....</b>	<b>160</b>
	<b>Appendix G: Snapshots of Forum Content .....</b>	<b>161</b>
	<b>Appendix H: Word Trees of Students' Interview Transcription Highlighting Relevant Statements.....</b>	<b>164</b>
	<b>Appendix I: Word Trees of Lecturer's Interview Transcription Highlighting Relevant Statements.....</b>	<b>167</b>
	<b>Appendix J: Word Trees of Forum Content Highlighting Relevant Statements.....</b>	<b>168</b>
	<b>Appendix K: Word Trees of Chats Content Highlighting Relevant Statements.....</b>	<b>170</b>
	<b>Appendix L: Computer Lab Guidelines.....</b>	<b>172</b>
	<b>Appendix M: Screenshots of Assigned Tasks.....</b>	<b>173</b>

## CHAPTER 1: INTRODUCTION AND BACKGROUND

### 1.1 Introduction to the Chapter

This chapter outlines the background of the study including the context of the case study and the rationale and justification for the research. It also introduces the research questions and defines some terms and concepts in the context of this research exercise.

### 1.2 Background

The University of Jos (UniJos) is a federal university located in the capital city of the Plateau State within the central part of Nigeria. UniJos is committed “*to provide education that is globally competitive and relevant to the needs of today’s employer and the developing challenges of Nigeria and beyond*”<sup>1</sup>. In view of this, it has adopted the use of Information and Communication Technologies (ICTs) as an integral part of the system to support and enhance research, teaching, learning and administration (UniJos ICT Policy, 2008)<sup>2</sup> in the achievement of this goal. In order to achieve this goal, it is critical to overcome the challenge of inadequate ICTs facilities, and the limited number of computers in computer labs especially in the department of computer science where it is essential for students to have hands-on practice in core programming courses.

The use of ICTs to enhance teaching, research and learning has been encouraged in higher education for several years (Tondeur, et al., (2016).

---

<sup>1</sup> UniJos website, [http://www.unijos.edu.ng/the\\_university/history.php](http://www.unijos.edu.ng/the_university/history.php) lines4&5

<sup>2</sup>The ICT policy of 2008 led to the creation of e-Learning strategic plan in 2008 and is now under review to become a policy i.e. e-Learning policy

UniJos introduces the use of computers for administrative purposes in the early 1990s (Jos-Carnegie Partnership Project, 2006). In 2004, an institutional ICT Strategic plan was put in place as a guide to encourage ICT penetration in faculties and departments with the aim of promoting ICT-driven development in teaching, learning and research within the university.

The year 2008 marked the emergence of ICT policy that led to the creation of an electronic or online learning (e-Learning) Strategic Plan (UniJos e-Learning Strategic Plan, 2008). All these were aimed at enhancing teaching and learning through the use of ICT tools. Also, the University in its quest for use of ICTs for teaching and learning, it deployed a centralised Learning Management System (LMS) called Knowledge Environment for Web-based Learning (KEWL) in 2004. It was later migrated to Modular Object-Oriented Dynamic Learning Environment (Moodle) platform in 2008, which is currently in use. Despite all these efforts, the problem of handling practical hands-on programming activities remains a challenge in the department of computer science of University of Jos, Nigeria. The challenge here is that the limited number of computers in the lab cannot accommodate all the students during practical sessions and the lecturer could not be able to attain to all the learners within the time frame for practical sessions.

The Computer Science department in University of Jos, started as a programme in the department of Mathematics until October 2012 due to lack of staff strength. Currently, only undergraduate programmes are available in the Computer Science Department. The Computer Science

undergraduate programme is a four-year course and eight cohorts had been graduated so far.

In the 1<sup>st</sup> & 2<sup>nd</sup> years of the programme, mostly Mathematics courses are taken by the Computer Science students and these are delivered in a blended mode, that is, face-to-face and online using the university's LMS. Students use lab computers, home computers and often their personal mobile devices at home and in the hostels to access the LMS to complete assignments and other activities online. In their 3<sup>rd</sup> and 4<sup>th</sup> years, programming courses are offered including the Java programming language which is a second semester course of year two, but is currently being offered as a second semester course in the third year.

The programming courses form the core of Computer Science studies and required students' hands-on practice for them to acquire programming skills and experience (Bowlick, Goldberg, & Bednarz, 2017). However, in UniJos context, practical classes are often not conducted and students learn only the programming syntax and theories without hands-on program coding, which in turn led to graduating unskilled programmers.

The aforementioned is observed from the fifteen (15) graduates (of different cohorts) employed in the ICT Directorate of the University of Jos where the researcher works. They were retrained to acquire requisite skills before being allowed to work on production systems. This is due to lack of adequate computers in the Computer Laboratory of the Computer Science Department, and resistance to the concept of 'Bring Your Own Technology' (BYOT) inside the physical computer lab (see Appendix L: Computer Lab Guidelines).

Traditionally, physical computer laboratories in Computer Science departments of universities are set up for students to carry out practical programming assignments. The ideal situation is to have a ratio of one-to-one (1:1) i.e. one student per computer during the practical classes (Islam, & Grönlund, 2016). However, the present situation in the Computer Science Department of UniJos is far from this. The cost of having and maintaining one computer per student is quite high.

Also, if the lecturers are to group their students to take turns and use the computer lab, it is difficult to find time per week per semester to cater for all the groups because of the large number of students require to use the facilities. Due to this constraint and the resistance to BYOT inside the physical computer lab, quite often the lecturers teach these practical-oriented courses without adequate lab facilities that would have engaged the learners, shaped and molded them into skilled programmers. This situation is similar to what Achibong, Oshiomu & Bassey (2010:204) referred to as “... *ill-equipped graduates*”...

'An activity system's view of learning programming skills in a virtual lab: a case of University of Jos, Nigeria.' The focus of this minor dissertation is to investigate how use of Virtual Lab could mediate students' hands-on programming skills acquisition, through transformative mediation of ICT tools. The virtual lab environment have no BYOT resistance like the physical lab since access to the lab by the users must not be in a confined physical lab. Thus, learners can use their devices to perform hands-on practical activities inside the virtual lab.

A virtual lab is not a real lab but a simulated lab environment using software; for this research work, the simulated lab was a plugin on the

LMS server. Access to the virtual lab was not restricted to a fixed physical space unlike the physical lab. Many users can access the virtual lab on the LMS server through a web interface, using other computers and mobile devices without BYOT resistance. Learners can access and use it concurrently at any time as long as they are given permission.

With virtual lab, students can access the lab using their devices remotely to complete and submit their assignments. The lecturer can easily assess, make comments, guide and coach each student online with feedback on their work using his/her technology (including devices such as private computers, laptops, and/or tablets). The virtual lab provides the lecturer with an option to set scripts and programs to evaluate every student's submissions, hence making the evaluation and feedback process easier (Robinson, & Carroll, 2017).

The Java programming course (with course code of CS202) is a three-credit unit course and the 2015 class has 68 students. The CS202 is one of the Object-Oriented programming courses that require a number of hands-on lab activities and students' active engagement. The course is structured to include 60% theory and 40% practical sessions; and the assessment has been 100% theory instead of 60% theory and 40% practical because of the aforementioned challenge in conducting practical sessions. The Department has one computer laboratory with 14 operational computers, which is not adequate to cater for the 'hands-on' practical programming requirements of this course. Therefore, it affects their practical skills and experience that supposed to groom them as potential programmers (Kori, et al., 2016; Savić, et al., 2016).

The affordances of the virtual lab mentioned above shows that it has the potential to mitigate the challenge of graduating unskilled programmers. The virtual lab can enable students to access lab and practice Java program coding repeatedly at their own pace (Heradio, et al, 2016; Hovardas, Xenofontos, & Zacharia, 2017) and also have the attention of their lecturer individually. The lecturer have the opportunity to help each students base on his/her Zone of Proximal Development (ZPD) through corrections, comments and feedback on their lab activities as maintained by Vygotsky (Barker, Quennerstedt & Annerstedt 2013; Engeström 2014:134-135; Roth, 2014; and Bozalek, Ng'ambi, Wood, Herrington, Hardman, & Amory, 2015: 46-47; Leonardo, & Manning, 2017).

Therefore, the virtual lab mediates between the lecturer and the students to enhance students' programming skills acquisition (Bozalek, Ng'ambi, Wood, Herrington, Hardman, & Amory, 2015:10-14, 46-57). Accessing the virtual lab is based on the concept of 'Use Your Own Technology' (UYOT) remotely where both the students and the lecturer gain access to the virtual lab on the Moodle LMS server using their devices through web access. The theoretical framework used for this research work is activity theory, to explain how use of virtual lab could mediate students' hands-on programming skills (Engestrom, 2017b; Engestrom, 2014).

### **1.3 Research Problem Statement**

Learning professional courses like Computer Science, Architecture, and Engineering requires a number of practical hands-on activities and scaffolding in order for the learners to be technically and practically

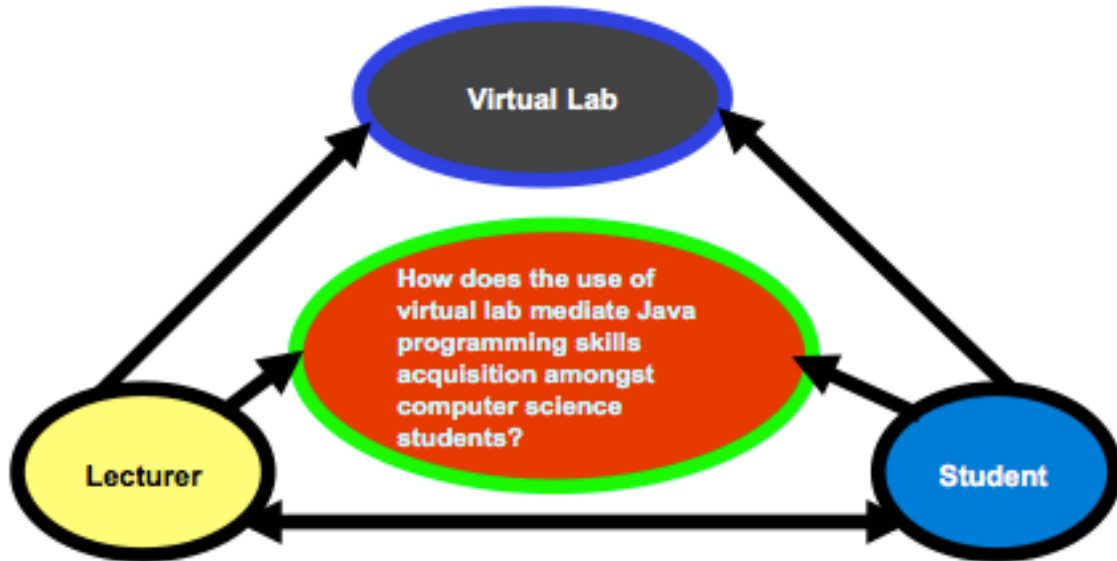
competent (Johns-Boast, 2014:199-201). In Computer Science, programming is one of the fundamental aspects that require thorough program coding, program testing, and program debugging by students (Kori, et al., 2016; Savić, et al., 2016). Lack of students' hands-on programming could be a serious setback for the learners because they will only acquired the theoretical knowledge without practical skills.

Also, from a pedagogical point of view, the learning process may not enable students to demonstrate their practical understanding of the learned concepts. The effect of this is that students graduate without programming skills and hands-on experience. From 'Experiential Learning' theory perspective, experiment "... *helps students to understand and grasp the relevance of the theoretical concepts they learn in class, i.e. to put theory into practice ...* (Johns-Boast, 2014:201).

Therefore, it will be difficult for them to get employed or when employed they may need to be retrained by the employer before they are allowed to work in a production environment (Acheampong, 2013; Bringula, Balcoba, & Basa, 2016; Baruah, Ward, & Brereton, 2017). This can also impact on the reputation of the department. In the context of Computer Science Department of UniJos, there is need for an alternative means of engaging students in hands-on programming practice while the lecturer guides them through the process. The use of virtual lab provides such alternative hands-on programming environment.

#### **1.4 Research Question**

The primary research question for this minor dissertation is: How does use of a virtual lab mediate Java programming skills acquisition amongst computer science students?



This research question embedded the following researchable subsidiary questions:

1. What is the objective of virtual lab programming?
2. How does the virtual lab programming mediate students' programming skills acquisition?
3. What are the teaching and learning practices evident in the virtual lab?

### 1.5 Research Objectives

The main objective for this research work is to find out whether use of virtual lab will enhance students' Java programming skills acquisition in the Computer Science department at UniJos; while the intervention was expected to offer the following benefits of virtual lab as a new pedagogical way of impacting knowledge and practical skills:

1. To provide alternative computer lab engagement
2. To provide flexible access to the lab for students to carry out programming tasks, and the lecturer to scaffold students' program coding ability.

3. To enable students' hands-on programming assessment where formative feedback can help enhance their skills (Robinson, & Carroll, 2017; Chen, DeMara, Salehi, & Hartshorne, 2017).

## **1.6 Purpose of the Study**

The purpose of this study is to investigate how use of the virtual lab as an emerging technology (in the context of UniJos) in conducting hands-on programming practical sessions for computer science courses with focus on Java programming language course at the UniJos, in Nigeria could mediate students' programming skills acquisition.

## **1.7 Definitions of Concepts and Terms**

Some terms and concepts that are commonly used in this research work are defined in the context of this dissertation as follows.

### **1.7.1 Learning Management System (LMS)**

Mauro, et al., (2017) define a Learning Management System as software used to deliver, track and manage education.

### **1.7.2 eLearning**

Pulido, Villamil, & Tarazona, (2017) defined eLearning as ICTs software tool or a set of computing applications that allow creation and management of spaces destined to teaching and learning through network or Internet. Su, Tzeng, & Hu, (2016) defined eLearning as processes of using electronic teaching and learning programs that are Internet-based technologies, as well as support systems provided by computers and the Internet with the aim of creating learning mechanisms and environment that are not bound by physical location.

### **1.7.3 Virtual Laboratory (Virtual Lab)**

Encalada, & Sequera, (2017:1) define virtual lab as collection of computing resources for simulation of experimentation and practical activities online for educational purposes. Therefore, the virtual lab is referred to as a simulated interactive playground or environment with the help of software tools for experimentation and problem solving.

### **1.7.4 Programming Language**

Ernst, (2017) defined programming language as a language that enable humans to communicate with a computer through a set of commands, instructions, and other syntax use to design and develop applications or a software program. A programming language serves as a vehicle or medium used by programmers to write logical instructions and scripts that can be understandable and executable by a computer (Cook, 2013:4-5).

### **1.7.5 Java Programming Language**

Gosling, Joy, Steele Jr, Bracha, & Buckley, (2014:1) defined Java programming language as ... “*a general purpose, concurrent, class-based, object-oriented language.*” Java programming language is concurrent (can execute collection of processes in parallel), class-based (allow inheritance of features) and object-oriented (that is, concepts are represented as objects with attributes that describe the objects), multithreading and portable across different platforms (Gosling, Joy, Steele Jr, Bracha, & Buckley, 2014).

### 1.7.6 Mediation

Mediation is a process of enabling or assisting negotiation; the enabler can be a tool like in technology mediation (Jalonen, Lakkala, & Paavola, 2011).

## 1.8 Chapter Summary

The application of ICTs in education is to supplement the teaching and learning processes. As noted by Jaffer, Ng'ambi and Czemiewicz (2007:131), educational technology provides additional pedagogies that can be use by educators and students to mitigate contextual, learning and teaching challenges in higher education environments. The use of a 'Virtual Lab' to mediate students' programming skills acquisition at Department of Computer Science in UniJos will be a pedagogical shift in conducting lab activities on the university's LMS online. Also, it is an opportunity to complement the physical laboratory while providing a flexible medium for students' engagement with practical programming tasks. Therefore, this dissertation will contribute in two (2) forms to the field of ICTs in Education or e-Learning, namely: provide a new way to promote hands-on programming education (especially in UniJos context), and opportunity to conduct programming exams online that will encourage online or distance learning in courses like Computer Science.

## 1.9 Thesis Structure

The dissertation is structured into five chapters. **Chapter one** covers the background, context, rationale, justification, research questions, and definition of terms and concepts in the context of this research work.

The **chapter two** reviews and unpacks the available literature, the concept and empirical research on the virtual lab, the virtual lab

development tools, and the theoretical framework (that is, activity theory) employed in this research. It also examines and critiques the theoretical and conceptual underpinnings that others have investigated.

The **chapter three** introduces the research design methodology (qualitative technique and descriptive research methods), data collection methods, instruments used and data analysis technique.

The **chapter four** presents, analysed and thoroughly discussed the research data collected.

The research findings are summarized in **chapter five**. This chapter also provides reflections on the research work and recommendations for adoption, implementation and future research in this area.

## **2 CHAPTER 2: LITERATURE REVIEW**

### **2.1 Introduction to the Chapter**

This chapter reviews the background and concepts of the virtual lab and its use for teaching and learning. Empirical research on virtual lab was reviewed, which includes the development of the virtual lab tools, such as the virtual programming laboratory (VPL) that was used to deploy the virtual lab on the LMS. It also discussed historic trends of the virtual programming laboratory and its features.

The chapter concludes with a discussion of the theoretical framework, that is, activity theory employed for this research.

### **2.2 Virtual Lab Overview**

Advancement in web-based technology introduces the concept of online activities like online or web-based learning, eLearning, mobile learning, remote lab, virtual lab and online experiments (Potkonjak, et al, 2016).

Wang, (2012:1745); Dalgarno, Bishop, & Bedgood Jr (2012:90) found that educators of professional courses such as electrical engineering, computer science and computer engineering have exhibited anxiety in embracing eLearning. This is because they felt it would be difficult to conduct some of the important components of their teaching through eLearning, especially conducting hands-on lab activities. The concept of virtual lab is relatively new and emerging (in the context of UniJos), although its implementation has been around for years (Heradio, de la Torre, & Dormido, 2016). It is worth noting that students can use home computers and mobile devices to access and complete lab activities in the virtual lab. The virtual lab further offers a convenient means for the

lecturer to assess large number of students' lab activities in the virtual lab than otherwise.

For some years now a great deal of exploration has been carried out and experimentation conducted on using ICT tools to conduct lab activities online (Wang & Philips, 2012; Heradio, et al, 2016; Rodríguez-del-Pino, Rubio-Royo & Hernández-Figueroa, 2012; Alkhaldi, Pranata, & Athauda, 2016). Currently, two major approaches for online laboratories have been identified, namely virtual labs and remote labs (Heradio, et al, 2016). Both uses web interface to access the laboratories, hence the name 'web-based laboratories'. Technically, a web-based lab is any lab that is accessed through the Internet/Intranet using a web browser, and this could be either a virtual or remote lab.

### **2.3 Virtual Lab Concepts and Empirical Research Review**

The concept of virtual laboratories emerges due to the quest to support students' laboratory practices and learning especially in the field of science and engineering (Bose, 2013; Petrović, et al, 2016; Heradio, et al, 2016; Diwakar, et al, 2016). The process became possible with advancement in ICTs and development in educational pedagogical practices (Potkonjak, et al, 2016). The concept first appears in the year 1984 with the conception of virtual instrumentation based on the fundamentals of programming; and in the 1990s, the concept of object-oriented programming was employed in the development of laboratory simulation (Oliveira, Marranghello, Silva, & Pereira, 2016).

The virtual lab is an interactive virtual environment that comprises of technologies, educational pedagogies, and human resources especially students and educators to perform practical activities (Potkonjak, et al,

2016; Soni, & Katkar, 2014). However, the concept of the virtual lab is not only to develop interactive tools that could promote a new culture in schools' learning processes. But also to embed new educational pedagogies that can enable student-centred learning processes through authentic learning (Potkonjak, et al (2016). The virtual lab offers students the opportunity and the environment to practice and demonstrate their understanding of theories and concepts learned; that is, it gives them the ability to apply their theoretical knowledge (Lewis, 2014; Tatli, & Ayas, 2013). Therefore, the virtual lab environment could provides an opportunity for students to perform and practice programming knowledge and concepts learned in theoretical classes at their own pace to acquire practical experience and skills.

The concept of virtual lab is improving due to rapid advancement and continuous development in ICTs, and the need to use ICTs is also increasing because of cultural changes (Potkonjak, et al (2016; Rodríguez-del-Pino, Rubio Royo, & Hernández Figueroa, 2012; Heradio, de la Torre, & Dormido, 2016). However, the concept is not to competes or replaces the traditional physical lab, instead, support and supplement the physical lab in situations like when the number of users outweigh the equipment in the physical lab or when there is need for frequent access to the lab for practical activities (Frerich, Kruse, Petermann, & Kilzer, 2016). According to Frerich, Kruse, Petermann, & Kilzer (2016) the concept of virtual lab has been promoted to advanced opportunities for integrating teaching, research and inter-disciplinary research activities. Therefore, the concept could be considered as a paradigm shift in ICT-based education delivery process.

Virtual Lab is an interactive environment used to conduct simulated experiments and a practice-playground for tasks like program coding and testing (Furberg, 2016; Hidayat, & Utomo, 2015).

Frerich, Kruse, Petermann, & Kilzer, (2016)) noted that a virtual lab could be viewed as a simulated lab environment using software application, while a remote lab is a non-simulated lab environment. This implies that a remote lab is a real physical lab that is accessed through the web or Internet remotely from a different location. Lemonds defines a remote lab “...as any physical equipment that is operated from a geographic location different than the location of the equipment using user interface software in order to learn or reinforce a concept” (2012:2). For instance, a computer-networking lab can be set up with real switches and routers where students located remotely from the lab can access the physical lab via the web to practice configurations of the switches and the routers (Zalewski, & Gonzalez, 2017).

On the other hand, software such as Digital Logic Builder (DLB)<sup>3</sup> or Easy Java Simulations (EJS)<sup>4</sup> can be used to simulate an Electrical Engineering Digital Logic Design lab environment (virtual lab – not a real lab). With this, students can access via a web interface through the Internet to perform practical experiments (Heradio, de la Torre, & Dormido, 2016). Oliveira, Marranghello, Silva, & Pereira, (2016) explained that use of virtual lab as a pedagogical tool eliminate damage to expensive equipment that could also be unaffordable or unsafe for students.

---

<sup>3</sup> DLB Website <http://www.cise.ufl.edu/~fishwick/dig/dlesp.htm>

<sup>4</sup> EJS Website <http://fem.um.es/Ejs/>

Hence, use of virtual labs in teaching and learning technical courses provide a new way of conducting practical classes that could be challenging in a given context. This description is relevant to the situation in the Computer Science Department of UniJos, where the cost of acquiring computers and other devices to equip a physical lab for a large number of students to have hands-on practice is not affordable. In such situation, a free and open source software tools like Virtual Programming Lab (VPL – a software plug-in designed for simulating virtual lab and compatible with Moodle) can be used to simulate the virtual lab environment for students to carry out hands-on activities (Oliveira, Marranghello, Silva, & Pereira, 2016).

Chen, Song and Zhang's investigation shows that use of virtual labs allow students to repeat hands-on practice multiple times, giving them the opportunity to see how changed parameters and values affects the output (2010: 3844). This feature of the virtual lab is an important one for Computer Science programming courses that required students to be engaged in a regular program coding, debugging and testing to perfect their programming skills. The programming practice in the virtual lab can take place anytime and anywhere as long as the students have Internet access.

Alkhaldi, Pranata, & Athauda, (2016) reviewed contemporary remote and virtual labs deployments and observed that use of virtual lab resulted in rich hands-on learning experience, better achievement of learning outcomes when relevant pedagogical framework, well planned content with regular educator's interactions with the learners is involved in the process. Their findings show that virtual labs provide learners with self-paced hands-on learning opportunities, ability to reset or retry

experiments without waste of resources, and flexibility to access lab environment. Mahajan, Kulkarni, & Diwakar, (2016) conducted a pilot study on how to use virtual labs to teach Mobile Communications in University of Mumbai. Their findings show 1) that the students were interested and motivated using the virtual lab, 2) improved understanding of core concepts by students, 3) that the students responded positive with course exit survey feedbacks, and 4) students improved performance at the end of semester. These findings indicated that the virtual lab have the ability to provides students with hands-on programming environment to practice programming concepts and knowledge acquired in theoretical sessions at their own pace.

In addition, the use of the virtual labs can promote and support student-centred learning and teaching pedagogy (Encalada, & Sequera, (2017; Dunn, (2017). This could also induce the students who are digital natives into using their mobile devices to practice programming (Šorgo, et al, 2017; Fernández, et al, 2017). Engaging students with programming activities in the virtual lab can attract and motivate them to practice programming concepts they learned in class, hence, promoting authentic learning (Cheng, Chen, Liu, & Huang, 2016; Bozalek, Ng'ambi, Wood, Herrington, Hardman, & Amory, 2015).

### **2.3.1 Virtual Lab Affordances**

The virtual lab technology has rich educational features for teaching and learning practical concepts, which promotes the virtual lab development and its use by learning institutions (Bose, 2013; Pellas, et al, 2017). These are affordances of the virtual lab that enhances its suitability for practical lab activities. For instance, the accessibility

affordance of the virtual lab enables users to easily access the virtual lab environment at convenient time to perform hands-on activities (Lewis, 2014). This feature is appropriate for practical programming lab activities and for distance learning programmes, where students can access the lab from different places. Also, it enhances the possibility to share the virtual lab across institutions.

The observe-ability feature of the virtual lab help users to observed the results or effects of their actions or activities performed in the virtual lab (Qvist, et al, 2015). The virtual lab has the ability to simulate real sensation of the practice environment (Qvist, et al, 2015; Tatli, & Ayas, 2013; Lewis, 2014). This affordance of the virtual lab can be leverage upon in a situation whereby there could be a risk or trouble experimenting with some equipment that can hurt or injured students or even damage the equipment.

The virtual lab has the interact-ability feature that enables many students to interact with it at the same time without any impact on its performance and functionality (Hovardas, Xenofontos, & Zacharia, 2017; Bose, 2013). The interactive affordance of the virtual lab makes it effective pedagogical resource for online education delivery, which encourages students to be at the centre and play active role in the learning process and provides them with hands-on experience (Oliveira, Marranghello, Silva, & Pereira, 2016). Soni, & Katkar, (2014) maintained that the virtual lab provides an innovative way for hands-on lab practice and enhances access to lab environment.

A virtual lab is a web-based simulated lab environment that required network connection to be accessed. With a network connection, students can access the lab environment any time at their own pace; while the

educator can monitor and manage the students' activities in the virtual lab and guide them (Farooq, & Khlad, 2013). The virtual lab provides an online platform for students to interface with lab environment and perform practical activities seamlessly. This platform also enables the educator to provide students with feedbacks either synchronously or asynchronously (Farooq, & Khlad, 2013; Hovardas, Xenofontos, & Zacharia, (2017).

Oliveira, Marranghello, Silva, & Pereira, (2016) considered the virtual lab as one of the most important online educational resources that offered students the opportunity to acquire practical experience and practice what they learned through the Internet. Virtual lab provides the required environment for students to demonstrate and convert their theoretical knowledge into practical knowledge and experience through lab practice (Tatli, & Ayas, 2013; Hovardas, Xenofontos, & Zacharia, (2017). Also, it provides the opportunity for students to revisit or repeat any incorrect lab assignments to deepen the expected experiences and skills; hence, the interactive affordance of the virtual lab offers students a transparent and pleasant hands-on learning environment (Tatli, & Ayas, 2013; Lewis, 2014).

Therefore, use of virtual lab for practical programming activities and learning can spin students into active thinkers that can construct their learning effectively and meaningfully instead of being passive observers (Lewis, 2014). In some situations for instance, lack of laboratories, crowded classrooms, and insufficient lab materials, practical sessions are conducted using demonstration approach. And in such situations, virtual labs can support and provide valuable lab environment and used as supplementary or alternative lab to physical lab (Tatli, & Ayas, 2013).

### **2.3.2 Teaching and Learning Practices in a Virtual Lab**

The virtual lab is a vital mediating tool for online (eLearning) teaching and learning practices for professional courses like Computer Science (Galan, et al, 2017). Teaching and learning practices in the virtual lab allows students to connect, interact, share, and learn from peers and others outside their classroom and school hours. The virtual lab environment embedded pedagogical strategies, technologies and learner's needs to enhance practical teaching and learning experiences (Cordeiro, Fonseca, & Alves, 2015).

Heradio, et al, (2016) and Brinson, (2015) maintained that the pedagogical techniques employed for teaching and learning in virtual lab environment should ensure optimal student engagement, promote student interaction with content, with peers, educators, and encourage reflective thinking. The teaching and learning practices in the virtual lab environment promote self-paced learning and also enable the learners to define and construct their individual practical understanding of the hands-on activities (Lewis, 2014). The virtual lab hands-on teaching and learning practices encourages inquiry-based learning, stimulate students' curiosity, interest, creativity, and critical reflections on the lab activities (Galan, et al, 2017). The pedagogical techniques appropriate for teaching and learning in the virtual lab include virtual (online) collaboration, problem-based learning, inquiry-based learning, experiential learning, and constructivist learning approach (Kaunang, et al, 2016).

Hands-on learning practice in the virtual lab can be bored for learners when it is not engaging. Therefore, the teaching practices in the virtual lab require the educator to plan, scaffold, moderate, and facilitate the hands-on learning activities so as to engage the learners in authentic

learning (Zhu, Yu, & Riezebos, 2016; Simpson, 2016). Using the virtual lab for hands-on practice requires that the educator constantly monitor, review and evaluate students' hands-on activities in the virtual lab to better guide and provide them with timely feedbacks (Kaunang, et al, 2016). These learner-teacher interactions can happen synchronously or asynchronously.

The teaching and learning practices in the virtual lab provides active learning opportunities, flexibility for students, and encourages learning by doing (Encalada, & Sequera, 2017). Therefore, the facilitator (educator) is required to schedule the expectations in terms of participation, pacing, and progress for timely completion for all students to follow. Another advantage of the virtual lab is that the teacher can also use the virtual lab in class to demonstrate concepts that could facilitate learning. Teaching and learning practices in the virtual lab can be quite rewarding and also challenging because it requires authentic student engagement with the hands-on learning process if not, the students may end up doing something else on the system (Kaunang, et al, 2016).

Therefore, teaching and learning practices in the virtual lab can be challenging for the educator because its required the educator to frequently be online to communicate with the students using methods like chats or forums' discussions. Setting expectations for both the students and the educator at the beginning is very important; this should include guidelines for when the students will expect the teacher online. The teacher needs to ensure that the students are engaged with the lab activities by creating such opportunity through student-led discussions and feedbacks. Also, the teacher needs to engage in one-on-one with each student to avoid students feeling deserted or lonely.

### **2.3.3 Virtual Lab Development Tools**

ICTs have opened a new sphere for teaching and learning with web-delivered interactive environment and offer a great improvement in communication within the academic community (Berenguel, et al, 2016; Al-Adwan, & Smedley, 2013). The ICTs tools provide a solid delivery and pedagogical framework that can be used to design interactive simulation-based learning tools like Virtual Lab (Al-Adwan, & Smedley, 2013; Juhary, 2014; Pellas, et al, 2017). With the recent advancement in ICTs development, simulation applications are becoming capable, reliable and robust for the design and implementation of virtual labs (Navaraja, Jain, Sengupta, & Kumar, 2016).

In this research, the virtual programming Lab (VPL) module was used as plug-in software for the Moodle LMS. This was because it provides features that better mitigate the constraints at hand than Easy Java Simulation (EJS) plug-in. Easy Java Simulations (EJS) is a free and open source plug-in for simulating a virtual lab and compatible with Moodle LMS, however, it is software more suitable for simulating engineering or architectural lab design activities than for coding programs in computer science (Navaraja, Jain, Sengupta, & Kumar, 2016; Galan, et al, 2016).

#### **2.3.3.1 Virtual Programming Lab**

The virtual programming lab was the preferred virtual lab development tool used for this research work because it has the necessary features to create programming activity system environment. The VPL, as a virtual lab development tool, has been developed over the years with improved features for learning and teaching. In the year 2000 Cao, Chan,

Cao & Yeung designed a system called WebVPL for online teaching and learning with a web interface that enable students to access lab servers with resources from anywhere remote to the laboratory servers (Wang, 2012). WebVPL does not have a feature that enable web-based editing and program coding for students. With WebVPL, students could only access the lab to download software from school server, follow interactive demonstrations and listen to tutorial sessions uploaded on the server.

In 2010, the University of Las Palmas de Gran Canaria of Spain came up with a stable version of their VPL (Wang, 2012). The VPL is a free and open source application designed as an activity module plug-in for a Moodle LMS (Rodríguez-del-Pino, Rubio-Royo & Hernández-Figueroa, 2012; Robinson, & Carroll, 2017; Pisani, & Carvalho, 2017), released under a General Public License (GPL). The version 1.4 was released in September 2011, version 2.0 in July 2012, version 3.0 in February 2014, and the version 3.1 was released in July 2014 and this was the version used for this research work. The version 3.1 VPL features include:

1. Provision for backup and restoration of data, grading, grouping of students, and access control based on roles.
2. Options for monitoring and controlling student task submissions, which provide the lecturer with an opportunity to control and manage students' activities in the virtual lab.
3. A friendly code editor component that allows users (especially students) to edit program files using a browser.
4. Displayed program files with program syntax highlighted, which makes program bug location and debugging very easy (Rodríguez-

del-Pino, Rubio-Royo & Hernández-Figueroa, 2012:80; Pisani, & Carvalho, 2017; VPL Website<sup>5</sup>).

Apart from the compatibility of the VPL with the Moodle LMS to simulate a virtual lab; it provide the lecturer with the affordance to create, assign, and monitor hands-on programming tasks and review students' lab activities on the virtual lab; thereby enabling a hands-on programming activity system in the virtual lab environment.

## 2.4 The Activity Theory

The theoretical framework for this study is based on Activity Theory (AT) where Engestrom (2014) explains how use of artifacts in activity system mediate learner's learning processes. These artifacts could be ICT tools such as mobile devices, LMS, and virtual programming lab. AT is a theoretical framework that can help understand, describe and explain learner's programming skills acquisition through the use of ICT tools (Aguayo, 2016). Activity Theory was conceived from the ideas of Russian psychologists Vygotsky, Luria, Leont'ev and others (Wilson, 2014; Bozalek et al., 2015).

A simple AT model is depicted using a triangle where the top node or vertex represents the entry point of mediating tools into the activity system and the other two vertexes denote subject and object (Bozalek et al., 2015; Engeström, 2017a) as shown in figure 1 below.

---

<sup>5</sup> VPL Website <http://vpl.dis.ulpgc.es/index.php/en/features>

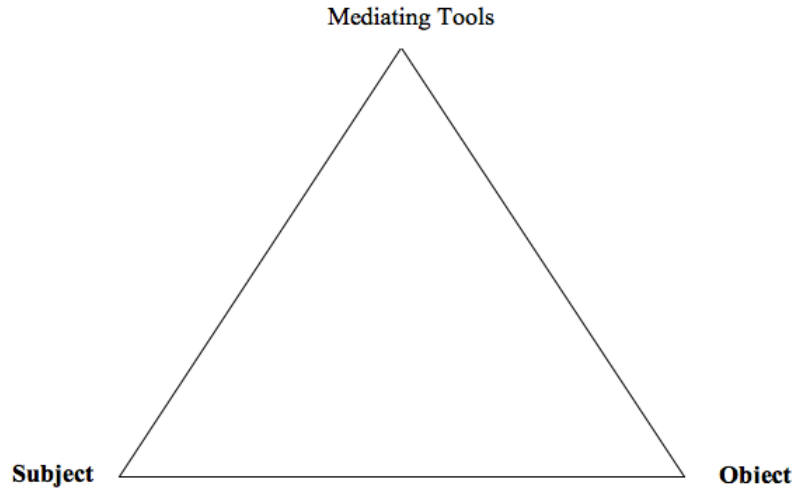


Fig 2.1: AT Model

Based on Vygotsky's concept of mediated action, the subjects are the participants (students and lecturer) in the activity (hands-on Java programming) motivated towards attaining or achieving a purpose or object(ives) of the activity (Wilson, 2014; Bozalek et al., 2015). The object represents the purpose or goal of the activity and the subjects' motives for participating in the activity are contradictions or tensions in the activity system (Bravo & Olavarria, 2013; Engeström, 2017b). The tools are social, cultural-historic material resources or artifacts that the subjects used to achieved the object (Wilson, 2014). The activity outcome is the result or consequences faced by the subject(s) based on their actions driven by the activity object, which could motivate, encourage or discourage the subjects from participating in future activities (Bravo Olavarria, 2013; Engeström, 2017b).

The choice of AT in this study is to used it as a lens to examine Java programming lab activity system where the lecturer used the virtual lab to mediate students' programming skills. Using AT as a framework helped draw relationships between students' hands-on practice,

engagement and hands-on skills acquisition. “Activity theory can be used as a methodological tool to investigate pedagogical change within a classroom” (Hardman, 2005: 1; Bozalek et al., 2015). The AT served as a lens to examine how a virtual lab mediates the acquisition of programming skills.

Activity Theory development currently has three generations (Engestrom, 2014): the first represents activity at an individual level where the tools (artefacts, ICTs inclusive) mediates between the subject and the object, hence, the first generation of AT is based on Vygotsky's concept of mediation, (Robertson, 2008; Hardman, 2005; Engestrom, 2014).

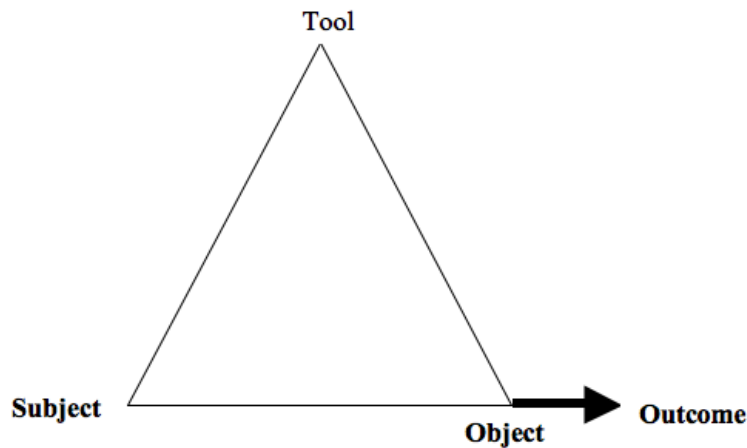


Fig 2.2: First Generation AT

The second generation was developed to represent an activity system at a collective level, as the first one is limited to only an individual level. This was developed based on Leontiev's three-level model of activity (Hardman, 2005; Engestrom, 2014), where rules (explicit or implicit) exist to guide and check responsibilities or division of labour among the activity's participants.

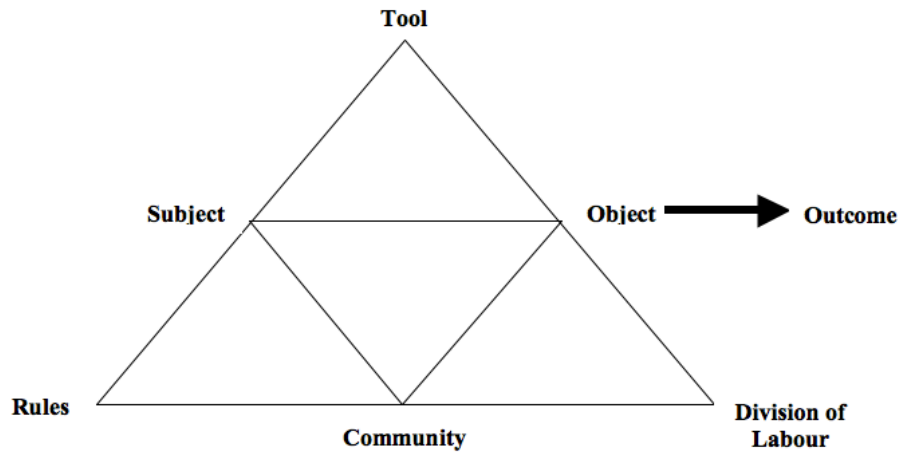


Fig 2.3: Second Generation AT

The second generation also failed to address two or more activity systems and this led to the development of the third generation which represents a network of activities (i.e. inter-activity) based on Engestrom's Activity Theory model (Engestrom, 2014). In this AT generation, the activity systems have a common object or boundary objects as shown in figure 4 below represented by a test tube-like shape.

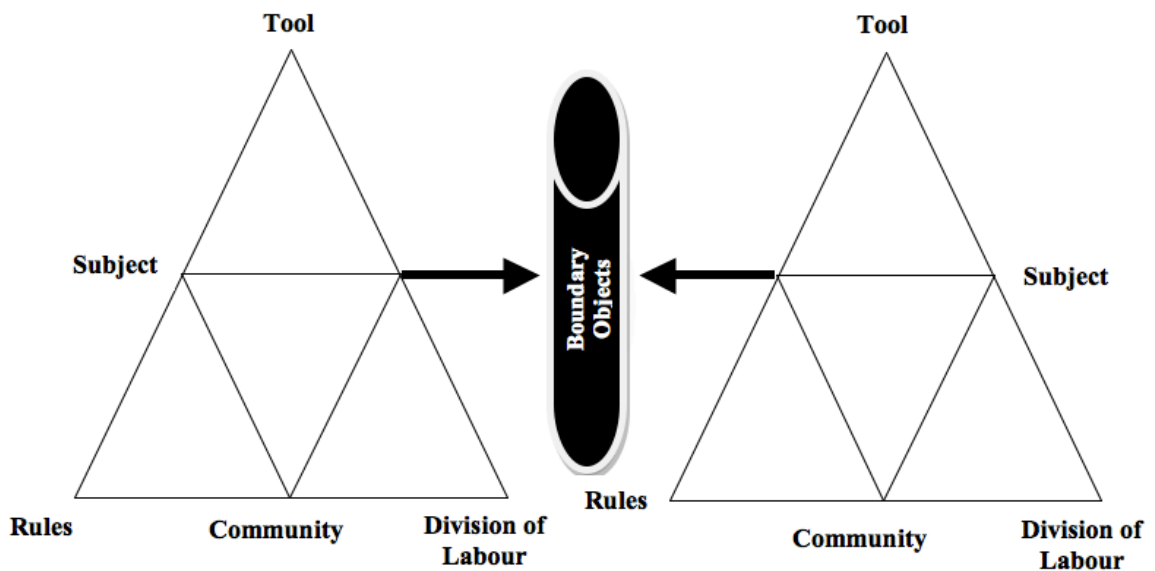


Fig 2.4: Third Generation AT

This study aimed at using the second generation Activity Theory because it involves a single activity system (i.e. virtual lab programming activity system) with collective individuals (students and lecturer) as indicated in figure 2.5 below.

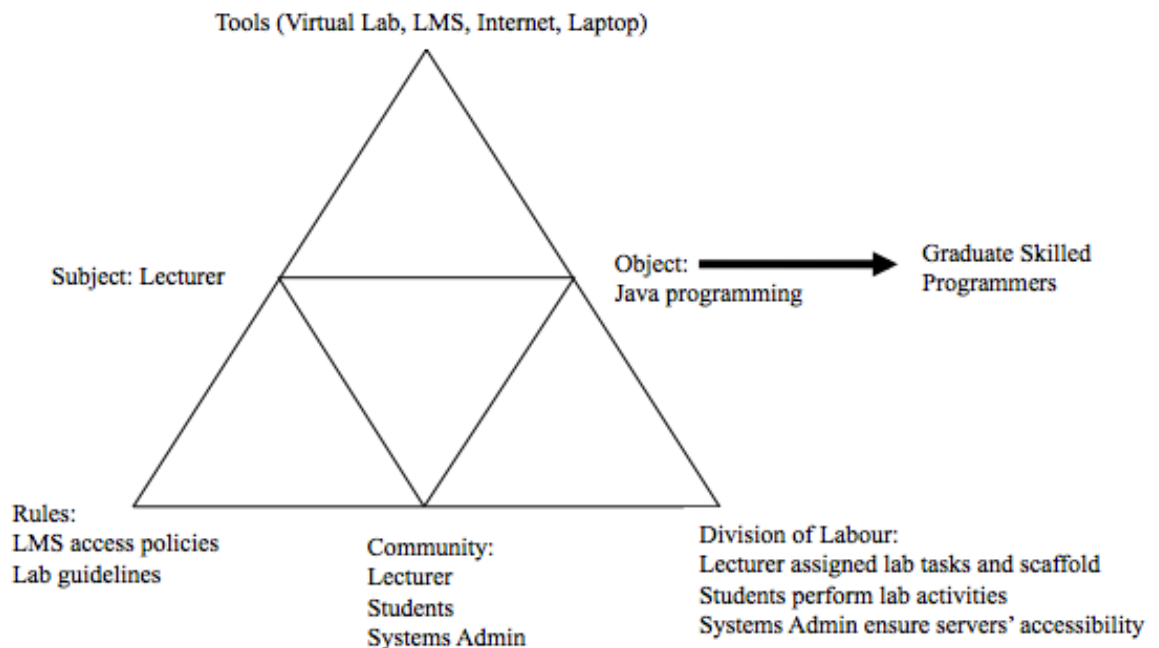


Fig 2.5: Hands-on Java Programming Activity System

### 2.4.1 Cultural-Historical Activity Theory (CHAT)

Activity Theory is a powerful theoretical lens to view and explain how interaction with ICT tools in learning activities could enhance hands-on skills acquisition (Engeström, 2017a; Clemmensen, Kaptelinin,

& Nardi, (2016). The activity theory offers a framework to analyse the socio-cultural influences of rules & regulations, community and division of labour in the same activity system (Behrend, 2014). The cultural and historical way of learning programming in computer science at UniJos involves more of the theoretical concepts than hands-on program coding. This is due to limited number of computers in the lab and resistance to BYOT.

The socio cultural aspect of activity theory helped describe who are carrying out the activities in the virtual lab environment (i.e. division of labour), explain which cultural rules and regulations guide the participants' interactions and performance in the activity system (rules and norms), and what cultural artifacts are at their disposal (Taylor, 2014; Behrend, 2014). For the virtual lab programming activity system in computer science at UniJos, the rules and regulations include access control to the virtual lab, activities instructions, datelines for submissions, and number of attempts. The theoretical lenses of activity theory helped view and explain how the socio-cultural life of the participants is displayed or exhibited in the learning environment (Virtual Lab) that is, Java programming activity system (Wilson, 2014; Clemmensen, Kaptelinin, & Nardi, 2016; Leonardo, & Manning, 2017).

Activity theory is referred to as Cultural-Historical Activity Theory (CHAT) because the social participation and interactions in an activity as maintained by Vygotsky can change dynamically when social and cultural conditions change (Wilson, 2014, Bravo Olavarria, 2013). In this context, moving from use of traditional lab to virtual lab, the participants' (students and lecturer) social participation and interactions

in the virtual lab changed from face-to-face to online or virtual (synchronous or asynchronous).

The concept of CHAT is developed based on ideas and socio-cultural perspectives of Vygotsky, Leontiev, and Engestron that humans learn by doing, act collectively and communicate through their actions. They create, use and adopt relevant tools in the process (Wilson, 2014; Taylor, 2014; Behrend, 2014). This human interaction in an activity system is regarded as the participation, while the actions of the subject on the object are mediated by the artifacts, and guided by the community rules and division of labour of the activity being performed (Bozalek et al., 2015; Engestrom, 2014).

CHAT can help a researcher to understand, analyse and explain the relationship between participants' thoughts, feelings and the activity they are doing (Java programming) using cultural resources or artifacts (Wilson, 2014; Bozalek et al., 2015). According to Leontiev, the object is key in directing the activity, while the subjects' actions changed or transformed the activity system's object in reaction or response to motives or contradictions /tensions within the activity system (Bravo Olavarria, 2013; Engeström, 2017b).

CHAT theorists described artifacts as cultural tools with meditational function, which can be determine based on local and historical position or context that help participants of an activity system to carry out an activity (Bozalek et al., 2015; Bravo Olavarria, 2013; Leonardo, & Manning, (2017). As the subjects (i.e. lecturer and students) performed actions on the activity multiple times using the artifacts, the object (Java programming) is being transformed many times to a stable finished product or outcome (programming skills acquired).

From CHAT perspective, rules guide and direct subject participation within the activity system community and also provide procedures for acceptable interactions among the community members (Leonardo, & Manning, 2017). The community comprises of the subjects in an activity system with varying interests, opinions and traditions forming a social group. In the community there exist a division of labour, in which each subject (e.g. lecturer) or subjects (e.g. students) have particular actions or tasks to be perform on the activity (Leonardo, & Manning, 2017). The division of labour could be horizontal (i.e. tasks are shared equally among members of the community) or vertical (tasks are assigned or shared unequal base on status) (Bravo Olavarria, 2013). In the hands-on Java programming activity system, the lecturer and the students vertically perform tasks; while among the students, the division of labour is horizontal with equal status.

In an activity system, there are different views or perspective about the object (i.e. the object is internally contradictory) among the community members, and these make the activity system unstable (Engeström, 2017b). The instability could be contradictions or disturbances. Also from the CHAT perspective, contradictions build tensions and can happen within components of an activity system (for instance, within object), between the components (e.g. between rules and the object) or between different activity systems (Engeström, 2017b; Bravo Olavarria, 2013). Disturbances on the other hand, are deviations observed in the flow of interactions within the activity system (Bravo Olavarria, 2013).

## 2.4.2 Review of Related Literature

Emily, et al (2016) investigated how use of Facebook as technological tool for teaching students could mediate their ability to apply the knowledge acquired in schools at workplace after graduation. They use activity theory as a theoretical framework and explored how it could be used as a lens to analyse how students' interaction with the technological tool (Facebook) enhanced their knowledge application skills at workplace when employed. Their findings show that 1) use of Facebook as a technological tool for students' interaction mediated their knowledge application skills; 2) AT is a useful theoretical framework to be used as a lens to analyse how students' interaction with technological tool could mediate their knowledge application skills.

Mlitwa & Van Belle (2011) used an analytical framework called ActAD, which is based on activity theory (Engeström's view) to explain their investigation of teachers' adoption of Course or Learning Management System (C/LMS) in universities in the Western Cape, South Africa. Their findings indicate that the ActAD framework is useful for applying AT in the context of eLearning technological tools at universities' level. Çakiroglu, et al (2016) employed activity theory as a framework to understand the actions and activities of both students and educator in an online programming course; using Adobe Connect web conferencing system as mediating tool. The research result shows that the lens of activity theory can be used to explore activity system actors' interactions and experiences in a programming course delivered online using web conferencing tool.

Rautkorpi, & Hero, (2016) investigated how experimentation-based pedagogies are used in higher education to improve students

skills in performing experiments. They used activity theory as a theoretical framework and their findings shows that there were important achievements in students' fieldwork practices and that the theoretical framework was adequate to analyse the collated data. Clemmensen, Kaptelinin, & Nardi, (2016) investigated how activity theory is used by researchers in the area of human-computer interaction (HCI) and how it worked out. Their findings show 1) regular and positive use of the activity theory by researchers in HCI, 2) the researchers adapted and contributed to the development of the theory.

These various findings demonstrated that the strength of activity theory is the ability to integrate or link the human and the technological elements to explain and described their interactions. The activity theory provided a structure or frame for categorizing, systematizing, describing and interpreting activities in activity systems. Thus, activity theory is a powerful descriptive and interpretive tool for research approach.

Therefore, activity theory is employed for this research to describe and explain students' interactions with the virtual lab for hands-on Java programming. Therefore, these previous studies have alerted me to the value of using Activity Theory in my study. The key idea of activity theory that shall direct this research work is the use of virtual lab as an artifact.

## **2.5 Conceptual Framework of the Virtual Lab Activity System**

### **Environment**

The figure 2.6 below is a logical schematic diagram of how the virtual lab environment is accessed by both the lecturer and the students. The virtual lab users accessed the lab from within the UniJos network

(Intranet) and from outside through Internet using private computers, mobile devices from homes, hostels, and at hotspots.

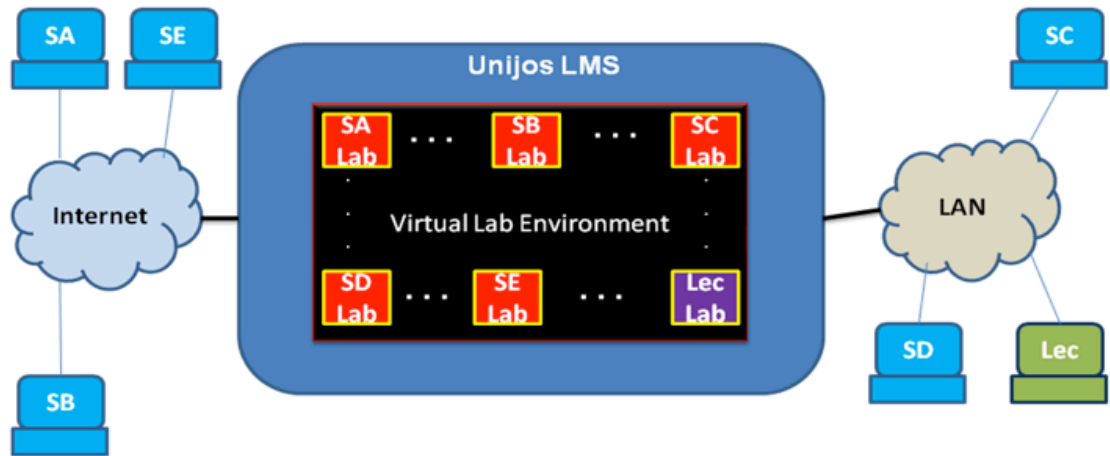


Figure 2.6: Logical Schematic Diagram of Virtual Lab Environment

Key: Student A=SA, Student B=SB, Student C=SC, Student D=SD, Lecturer=Lec., Local Area Network=LAN

An analytical framework based on Activity Theory shown in Figure 2.7 describes the virtual lab programming activity system and how it could mediate learners' hands-on programming skills acquisition. The activity system based on this framework is depicted in Figure 2.8 below. The activity framework comprises of six activity system components that make up the teaching-practice-learning programming work activity, that is, subject (actors), tools/mediators, tensions/contradictions, objective (motives, goals), actions (virtual lab programming), and outcomes (Mlitwa & Van Belle, 2011, Engestrom, 2014).

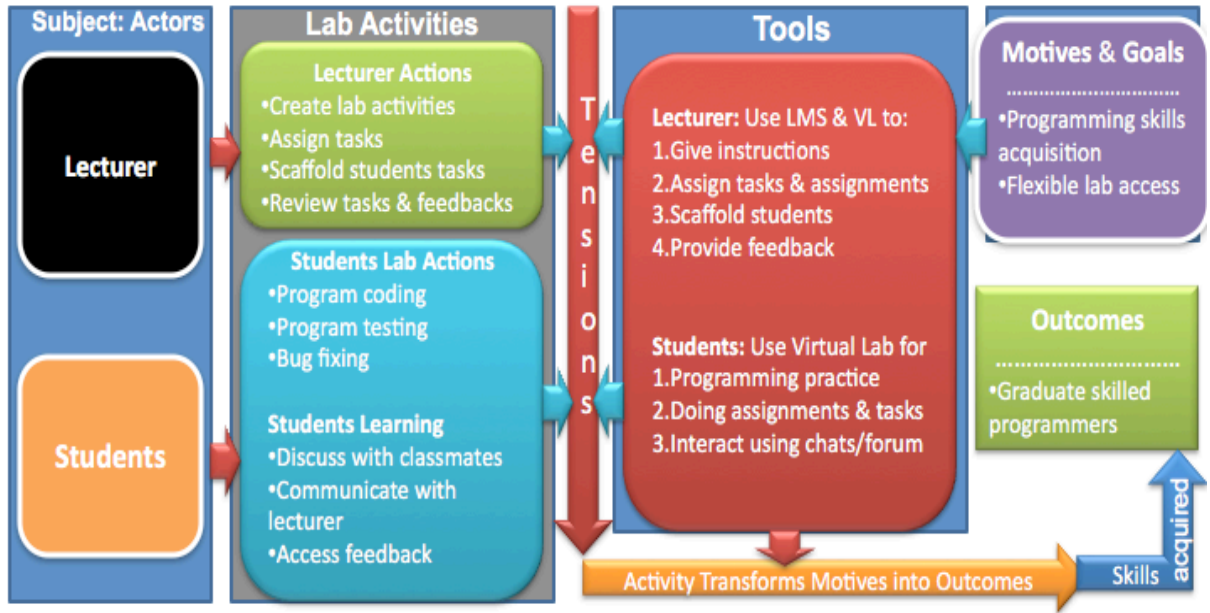


Figure 2.7: An Activity Theory-Based Framework for Programming Skills Mediation via Virtual Lab Environment (Analytical Framework).

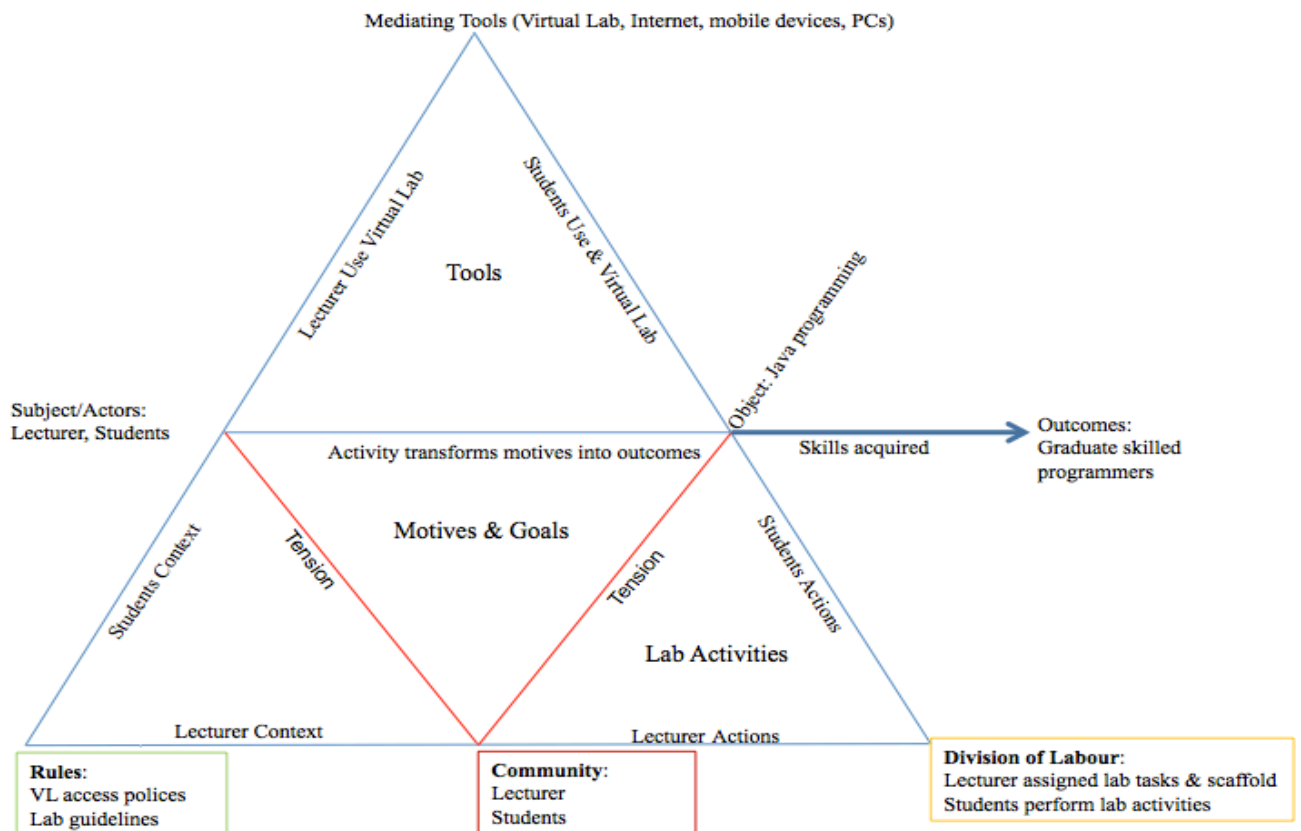


Figure 2.8: Virtual Lab Java Programming Activity System

The main activity objective from the framework is the hands-on Java programming practice using the virtual lab environment. The common object(ive) is the acquisition of practical programming skills by students and the subject or actors of the system include the lecturer and students. The activity system community includes the lecturer and the students (Engestrom, 2017b; Engestrom, 2014). The major tools for this mediation were the virtual lab, Internet connection, Local Area Network (LAN) or Intranet, mobile devices (laptops, notebooks, and tablets), and Personal Computers (PCs). The actions taken include the lecturer accessing the LMS to assigned programming tasks for students and scaffold the students' activities in the virtual lab. The students accessed the virtual lab to perform the assigned lab activities by coding programs and running or testing them (Engestrom, 2017b; Engestrom, 2014).

The primary anticipated contradictions in the activity system include the lecturer and students' motives and goals. The outcome of the activity system is to graduate computer science students with practical programming skills (Engestrom, 2017b; Engestrom, 2014).

## **2.6 Chapter Summary**

Innovations in web technology enhance development of applications that support online hands-on practice through online laboratories (Juhary, 2014). The online laboratories, especially the virtual labs are simulated lab environments that can be accessed by many users at the same time and anywhere via a web browser. This represents individuals and group actions that are embedded in a collective activity system on the virtual lab (Engestrom, 2014).

There are many software tools that can simulate lab environment online for different forms of hands-on practice like digital design, chemistry titration, and program coding. There are both proprietary and open source software tools e.g. VPL. Virtual lab is important for conducting hands-on programming practice where physical equipment is not enough and there exist restriction to BYOT inside a physical computer laboratory. Virtual lab gives learners the opportunity to repeat or practice program coding many times to master concepts and skills.

The theoretical framework for this research work is CHAT, which helps view how use of ICT tools mediate learning process and explain the socio-cultural changes in the system. A simple model of activity theory is represented by a triangle and there are three generations of the theory each representing a separate form of activity systems. The choice of activity theory for this research is to examine programming lab activity system where both the educator and students use the virtual lab to mediate students' programming skills. A conceptual framework of the virtual lab activity system environment was designed to indicate how individual and group actions or collective activity system in a virtual lab was conducted. Also, an analytical framework based on activity theory was designed to show how the virtual lab programming activity system could mediate practical programming skills acquisition.

### **3 CHAPTER 3: METHODOLOGY**

#### **3.1 Introduction to the Chapter**

This chapter discusses the research design, which employs qualitative technique and descriptive research methods. The process of selecting the research participants and the criteria used are outlined here.

The methods of data collection and instruments include, interview and content analysis of the virtual lab activities (interactions on chats and forum). The data analysis technique used is ‘thematic analysis’ and a software data analysis tool called Nvivo was used for the qualitative data.

#### **3.2 The Research Design**

The research work was conducted in a single natural setting, focused on a small number of participants with the aim of acquiring rich and in-depth data. The research involves fieldwork, where I collected data from participants’ collective activity system and therefore a qualitative design was employed and the research is descriptive in nature.

##### **3.2.1 Qualitative Research Methodology**

Qualitative research method is useful in providing answers to questions of the form “what” and “how” about human opinion (e.g. using virtual lab for practical classes), and experience (e.g. experience with virtual lab) that could be hard to answer using quantitative-based method of data collection (Creswell, 2013). The qualitative research method was used because it is a good tool to address educational questions like how use of ICT tools could mediate learners’ acquisition of programming skills, and how both learners and educator interact within an activity system (either online or in physical classes).

Qualitative research method is discipline-independent and offers an open design concept (Maxwell, 2008:215), which makes it appropriate for use in ICT in Education research work.

### **3.2.2 Descriptive Research Methodology**

The descriptive research method helps in describing, explaining and interpreting situations that occurred/happened in a specific place and time (e.g. virtual lab hands-on programming activities). This research is case study-based; therefore, the choice of descriptive research method that is case study-based. Descriptive research method involves describing and interpreting situations or activities occurring in the present. This technique is good in representing and/or presenting the opinions or meanings the participants in an activity have; that can extend the experience or add value/strength to what is already known in previous research works (Gray, 2013; Loeb, et al, 2017).

### **3.3 Case Study Selection**

The case study involves one lecturer as a participant and the criterion is that the lecturer should be the one teaching the CS202: Java Programming course. Six students were selected by the lecturer to form the students' sample using a criteria that: 1) three students should be 'Direct Entry' (i.e. students that have obtained Diploma certificate, who started their degree programme in the second year – '200 level'), and 2) the other three students are normal entry students (i.e. students who started their degree programme in the first year – '100 level' without any advanced qualification), i.e. directly from high school or with secondary school certificate. These make up a total of seven participants for the research work; and this selection technique was used for the purpose and

motive of acquiring rich and in-depth data. Both the lecturer and the participating students have experience with LMS as educator and learners respectively.

### **3.4 Data Collection Methods and Instruments**

In the virtual lab, the lecturer assigned lab activities (Java programming tasks – e.g. write a Java program to determine the upper bound of a two dimensional array) while the students complete the lab activities by coding programs, testing programs, fixing bugs and submit them for the lecturer’s comments and feedback. The whole Java programming activities in the virtual lab was for a period of three weeks. The hands-on programming tasks include the following topics:

1. Write a simple Java program that will search for a word inside a string
2. a) Write a Java program to determine the upper bound of a two dimensional array, b) Write a simple Java program that will extend an array after initialization
3. a) Write a program in Java that print summation of n numbers, b) Write a program that will implement stack
4. a) Write a Java program that use method for calculating Fibonacci series, b) Write a Java program that use method for calculating Factorial of a number
5. Write a simple Java program that create different shapes using Applet.

See some screenshots of the assigned tasks in Appendix M.

The virtual lab was used to conduct only the practical sessions; that is, the theoretical aspects of the course were not taught using the virtual lab. The practical programming sessions were conducted for this research intervention using the virtual lab and this was the first time for the lecturer to use virtual lab. Hence, the activities for the virtual lab were designed differently after the course has been taught.

To gather the appropriate required data for this research work, the following methods of data collections were used for collecting the research data after the three weeks lab activities.

#### **3.4.1 Interviews**

Interview questions were developed and administered during the interview interaction with the students' respondents; while a semi-structured interview was administered to the lecturer, that is, the respondent. The interviews were recorded in audio format only without video having obtained respondents' permission and consent. The recorded interviews were imported into Nvivo and transcribed them for analysis.

#### **3.4.2 Content Analysis**

The virtual lab activities were virtually observed online and the contents generated were analysed to see how use of the virtual lab could mediate hands-on Java programming skills acquisition. Hence, I was added as system administrator to the course on the LMS to be able to access and analyse the contents of the activities, these contents include the chats and forum. The chats and forum contents were also imported into Nvivo and transcribed them for analysis.

### **3.5 Data Analysis Technique**

A thematic analysis was used as a technique to codes or categorized the collected information, where patterns were identified from the data and mapped data to those sorted patterns. Related patterns were grouped into sub-themes, which later developed into themes; and, the research theoretical framework (AT) was later used to analyse the themes base on the programming activity system.

#### **3.5.1 Thematic Analysis**

Thematic analysis as a categorising strategy for qualitative data, is independent of discipline or epistemology (Clarke & Braun, 2014); and its choice for this research work is because of its flexibility and to ensure that themes naturally emerge from the collected data instead of being pre-determined or imposed by the researcher. Thematic analysis also enables simultaneous occurrence of data collection and analysis, that is, it offers the opportunity for “... on the spot analysis” (Dawson, 2009:120). The data analysis for this research was based on Clarke & Braun, 2014) idea and approach to thematic analysis.

A theme captures vital facts from the collected data in relation to the research question. It also presents or represents a given pattern of response or meaning by respondents from the collected data (Clarke & Braun, 2014). The research data collected, that is, the interviews’ data and the content generated in the forum and chats were thematically sorted and categorized into themes, which were later analysed using the research theoretical framework.

This process include the researcher familiarising himself with the data and transcribed the interactions, read/re-read the transcripts and

compared with the audio records, after then initial codes or patterns were identified. Relevant patterns were sorted or combined into themes; and the themes were reviewed and refine to cohere together meaningfully. Then, the themes were named appropriately, and finally the report or interpretation of the results using the theoretical framework.

### 3.5.2 Data Analysis Tools

Though analysing data mechanically (Dawson, 2009) is a process that could make the researcher more familiar with the data he/she collected; a computing software tool was used to identify patterns and developed them into categorized themes to ensure accuracy, appropriateness of the process and save time. A software tool called Nvivo (standalone copy was acquired) was used for coding the research data. Nvivo was selected as a tool out of many software tools for analysing the data because it is user-friendly, good for data analysis independent of researcher's materials, discipline and work style (Villar, & Papoutsis, 2013; Talanquer, 2014; Smith-Glaviana, 2016). It has a powerful feature for querying and uncovering subtle trends in data bank; compatible and work with data captured in different formats like Microsoft Word, Portable Data Formats (PDF), pictures, spreadsheet, audio and video files, social media data, and web pages (Villar, & Papoutsis, 2013; Talanquer, 2014; Smith-Glaviana, 2016). Nvivo can also share data with other applications like Excel. Tabulated below is a matrix of questions, data collection instruments, source of data and data analysis for the research.

Subsidiary Questions	Follow-UP Interviews	Content Analysis
What is the objective of virtual	Six students and	

lab programming?	one lecturer	-
How does the virtual lab programming mediate students' programming skills acquisition?	Six students and one lecturer	Analyse content generated by participants
What are the teaching and learning practices evident in the virtual lab?	-	Observe and review students lab activities (perform content analysis)
Data Analysis	Thematic Analysis Using Nvivo	Thematic Analysis Using Nvivo

Table 3.1: Matrix of Questions, Data Collection Instruments, Source of data and Data Analysis

After the data has been collected and coded into themes, the theoretical framework, that is, Activity Theory was thoroughly used to view, explain, interpret, and analyse the collated research data.

### 3.6 Research Ethics

Research ethics are contextual ways or norms for conducting research in an acceptable manner, though sometimes they are perceived as simple common sense in carrying out research involving human beings or animals. Some of these research ethics are being observed, applied, or interpreted differently by different institutions, departments or professions in their context, although all point to the same goal. For this research work, the Computer Science department was contacted for permission to use one of their courses for my research and consent granted. The consent of the course lecturer and the sample students were also granted.

The department has no departmental ethics on research activities but the university's research guidelines were adhered to, to avoid what may be consider research error. The university's research guidelines include: human subject protection, quality and integrity of research, conduct of research publications, copyright and patenting policies, human rights, data sharing policies, and confidentiality rules. The university research policy maintained, *“In carrying out research, professional ethics unique to particular discipline shall be observed”* (Research Policy for University Jos, 2011:P.13).

I promised to treat the data collected with respect because as noted by Dawson (2009:P.149) *“research process intrudes on people's lives... some people may find participation a rewarding process, whereas others will not.”* The data collected in the process of this research shall be treated and stored in such a manner that anonymity and confidentiality of the research participants are ethically protected. Although Dawson (2009:P.150) maintained that *“... information given by research participants in confidence does not enjoy legal privilege”* but if it means surrendering the information in court or to any law enforcement personnel, I will inform the participants before giving it out.

### **3.6.1 Code of Ethics**

Code of ethics was presented to the research participants before the hands-on Java programming activities in the virtual lab and the follow-up interviews. The code of ethics captured how the data collected will be used. The code of ethics is as shown below, as adopted from Dawson (2009).

Ethics	Research Stand Point
Anonymity	No name and address will be use or capture in the research final report. The information provided by participants will be store in a form that cannot be traced back to them by a third party.
Data Protection	I will comply with University of Jos' research policy guidelines
Confidentiality	I guaranteed that the information you will provide on the virtual lab activities and during interviews will not be disclosed to a third-party without your consent.
Participant Comments	As participant of this research, you will be informed of the research process and your comments will be attended to, to effect necessary changes. The final analysed data will be made available for your inputs on its correctness and interpretation.
Final Report	The research final report will be submitted to UCT, a copy to University of Jos, and department of Computer Science. Due to the anticipated size of the research report a succinct research report will be given to any participants who requested.

Table 3.2: Code of Ethics (Adopted from Dawson, 2009)

### 3.6.2 Validity

The validity threats to the conduct and conclusion of the study and the countermeasures that were taken are described as follows:

Customising the interviews to suite researcher's need as ascertain by Maxwell (2008:P.243) that “*what the interviewee says is always a function of the interviewer and the interview situation*” is a validity threat to the interview data. This validity threat was control or minimised by “avoiding leading questions” during the interviews with the participants and the interviews were conducted under an atmosphere that participants were free to expressed their feelings and views without being tell-guided.

Another form of validity threat is researcher's manipulation of the research set-up especially for this study that involved a virtual lab environment. A measure to avoid a situation described by Maxwell (2012:P.139), as “Potemkin village” or act of hiding undesirable truth,

for the validity of this research work was that the course lecturer is not the researcher. Respondents' validation of the analysed data was carried out to device a way to get feedback from the respondents about the correctness of their views' representation or presentation. According to Maxwell (2012:P.126) "*this is the single most important way of ruling out the possibility of misinterpreting the meaning of what participants say or do...*"

### **3.7 Chapter Summary**

The chapter discussed the research design, which was based on qualitative design and descriptive in nature. The discipline-independent nature of the design method makes it appropriate for use in this research. The research participants include one lecturer and six students to enable access to rich and in-depth data. Thematic data analysis technique was employed because of its flexibility and guarantee of natural emergence of themes out of the collected data without being influenced (Clarke & Braun, 2014; Dawson, 2009). A software tool called Nvivo was used as the data analysis tool for this research work because of the rich features it has (Villar, & Papoutsis, 2013; Talanquer, 2014; Smith-Glaviana, 2016). The research theoretical framework, that is, activity theory was used to view and explain the coded themes.

A matrix of questions, data collection instruments, source of data, and data analysis method is tabulated in Table 3.1 to indicate their relationship.

## **4 CHAPTER 4: RESEARCH FINDINGS AND RESULTS DISCUSSION**

### **4.1 Introduction to the Chapter**

This chapter covered the data presentation of the research work; visualization of the data; analysis of all the data collected from the instruments using AT; and the discussion of the results. The results include the interviews and the contents (chats and forum) generated from the virtual lab activities.

### **4.2 Presentation of Data**

The data collection process involved six students performing Java programming tasks or activities in the virtual lab while the course lecturer scaffold and provide feedbacks to students' online for a period of three (3) weeks. The researcher observed (virtually) the students' activities in the virtual lab; and also conducted follow-up interviews with each student and the lecturer on their experience with the virtual lab environment. The data collected using the research instruments are presented as follow.

#### **4.2.1 Students Interview**

Each of the participating students was interviewed separately after performing their hands-on programming exercises in the virtual lab (as shown on the screenshots in appendix A). This sequence was followed to ensure that the participants experienced the virtual lab environment before the interview, so that their responses should be based on their programming experience with the virtual lab.

The interviews were recorded in audio format only without video having obtained respondents' permission and consent. The recorded interviews were imported into Nvivo and transcribed. Presented in appendix D are

snapshots and full text extracts of the transcription from Nvivo environment. Shown below is part of the transcription.

The screenshot displays an audio player interface for a file named "Students Interview". The interface includes a video player area (currently black), a waveform visualization, and a transcript table. The waveform shows a peak at 00:01:22.9. The transcript table below lists two segments of audio with their start and end times and the corresponding text.

Start Time	End Time	Transcript	Speaker
00:00:07.7	00:02:27.6	The virtual lab was very easy to access; however there was a network challenge i.e. the Internet connection. The virtual lab was very easy to use. The virtual lab is a good idea that enables me to practice program coding at leisure time and I actually work on my exercises while on transit. It is an opportunity to put down ideas in practice as they come at any time and encourages more practice; and I gain more skills on programming using the virtual lab. I prefer the virtual lab environment to the traditional lab because in virtual lab I am at ease unlike the tension attached to the normal traditional lab and in virtual lab environment I express myself better. I recommend improvement on the network quality.	Student1
00:02:27.7	00:05:08.1	The virtual lab was easy to access, however there was network problem. The virtual lab was easy and friendly to use. It is good and it will help students to practice program coding more. It is an	Student2

#### Transcript

The virtual lab was quite easy to access by typing in my login details then instantly I was able to access the VPL environment. The virtual lab is very friendly but I will also like to add that there may be a few limitations that I notice like not having the full compiler as on desktop. It is good for testing programs on the move, that is, I could have an idea that comes to mind I can just type (write the code) and test it, I can do this any time as long as I have Internet access. Using the virtual lab will improve my programming skills very well. I definitely preferred the VPL because of easy accessibility, and issue of having hardware (computers in a traditional lab) is a problem, while with VPL either with a phone or any capable device I can have access to a full programming compiler (environment) that I can find my programs. Cost-wise the VPL is very cost-effective because we will not have individual system to serve individual students; students can bring their systems not necessarily computer systems but their tablets or cell phones. I will really urge the University and the department to take this very seriously to go beyond just one programming language (i.e. it

Fig 4.1 Students' Interview Transcription Snapshot and Extract

#### 4.2.2 Lecturer Interview

The lecturer was also interviewed after conducting the virtual lab activities with the students.

The interview was semi-structured and recorded in audio format only without video having obtained the respondent's permission and consent. The recorded interview was imported into Nvivo and transcribed. Also, presented below is a snapshot of the transcription and shown in Appendix E are snapshots and full text extracts of the transcription from Nvivo environment.

Name	Nodes	Refere...	Created On	Created By	Modified On	Modified By
Experience with the VPL	11	70	10/1/15, 10:21 PM	J	10/1/15, 10:23 PM	J
Lecturer Interview	0	0	Today, 11:02 PM	J	Today, 11:22 PM	J
Students Interview	0	0	9/26/15, 11:31 PM	J	Today, 3:21 PM	J

Start Time	End Time	Transcript	Speaker
00:00:01.1	00:04:57.8	<p><b>What can you say about the accessibility of the virtual lab?</b>            The virtual lab is accessible anytime anywhere as long as you have login details; with the virtual lab I was able to set Java programming assignments for students and check their submissions using my iPad. <b>How easy was using virtual lab since this is your first time to use it for teaching?</b>            Using the virtual lab was surprisingly very simple. I was able to view and comments on students' lab activities online even at home. <b>Did the virtual programming lab environment enable you to manage your practical classes?</b>            The virtual programming lab environment is an ideal lab for contemporary program coding teaching and learning because assisting learners in the virtual lab environment is much easier for a large class compare to normal lab. I was able to attend to each student in the VPL environment. Also the virtual lab activities encourage introverts' students to talk online.</p>	Lecturer

#### Transcript

#### **What can you say about the accessibility of the virtual lab?**

The virtual lab is accessible anytime anywhere as long as you have login details; with the virtual lab I was able to set Java programming assignments for students and check their submissions using my iPad. **How easy was using virtual lab since this is your first time to use it for teaching?**

Using the virtual lab was surprisingly very simple. I was able to view and comments on students' lab activities online even at home. **Did the virtual lab environment enable you to manage your practical classes?**

The virtual lab environment is an ideal lab for contemporary program coding teaching and learning because assisting learners in the virtual lab environment is much easier for a large class compare to normal lab. I was able to attend to each student in the VPL environment. Also the virtual lab activities encourage introverts' students to talk online. Scaffolding students' lab activities in the virtual lab was lovely because they received instant feedbacks. **With your experience now can you consider the virtual lab an opportunity to enhance learners' programming skills?** I must confess that the virtual lab experience has shaped my pedagogical thoughts and approach to teaching programming courses. The virtual lab is very useful especially for large classes and for teaching computer age students who like self-pace and independent practice.

Fig 4.2 Lecturer's Interview Transcription Snapshot and Extract

### 4.2.3 Virtual Lab Activities' Contents Generated

The researcher viewed the virtual lab activities with his access to the Java programming course on the LMS environment (see a visual relationship between an LMS and virtual lab in appendices B and C).

The students performed the activities by coding and testing their programs as shown in the screenshots below before submitting a final copy of each task.

The screenshot displays a web-based Java programming environment. The main heading is "Java Programming Language". A breadcrumb trail shows the path: Home > My courses > Miscellaneous > CS202 > Java Applets > Write a simple Java program that create different ...

On the left, a "NAVIGATION" sidebar lists various course elements, including "Current course" and "CS202" with sub-items like "Participants", "Badges", "General", "Java Strings", "Data Structure", "Program Control Flow", "Methods", and "Java Applets". The selected activity is "Write a simple Java program that create different ...".

The main content area has tabs for "Description", "Submissions list", "Similarity", and "Test activity". Below these are buttons for "Submission", "Edit", and "Submission view".

The central workspace features a menu bar with "File > Edit > Options > Fullscreen | Save Run Debug Evaluate Console | About". Below the menu is a code editor window titled "Create Applet" containing the following Java code:

```
1 import java.applet.*;
2 import java.awt.*;
3
4 public class Shapes extends Applet{
5     int x=300,y=100,r=50;
6     public void paint(Graphics g){
7         g.drawLine(30,300,200,10);
8         g.drawOval(x-r,y-r,100,100);
9         g.drawRect(400,50,200,100);
10    }
11 }
```

To the right of the code editor is a "Console" window, which is currently empty and black.

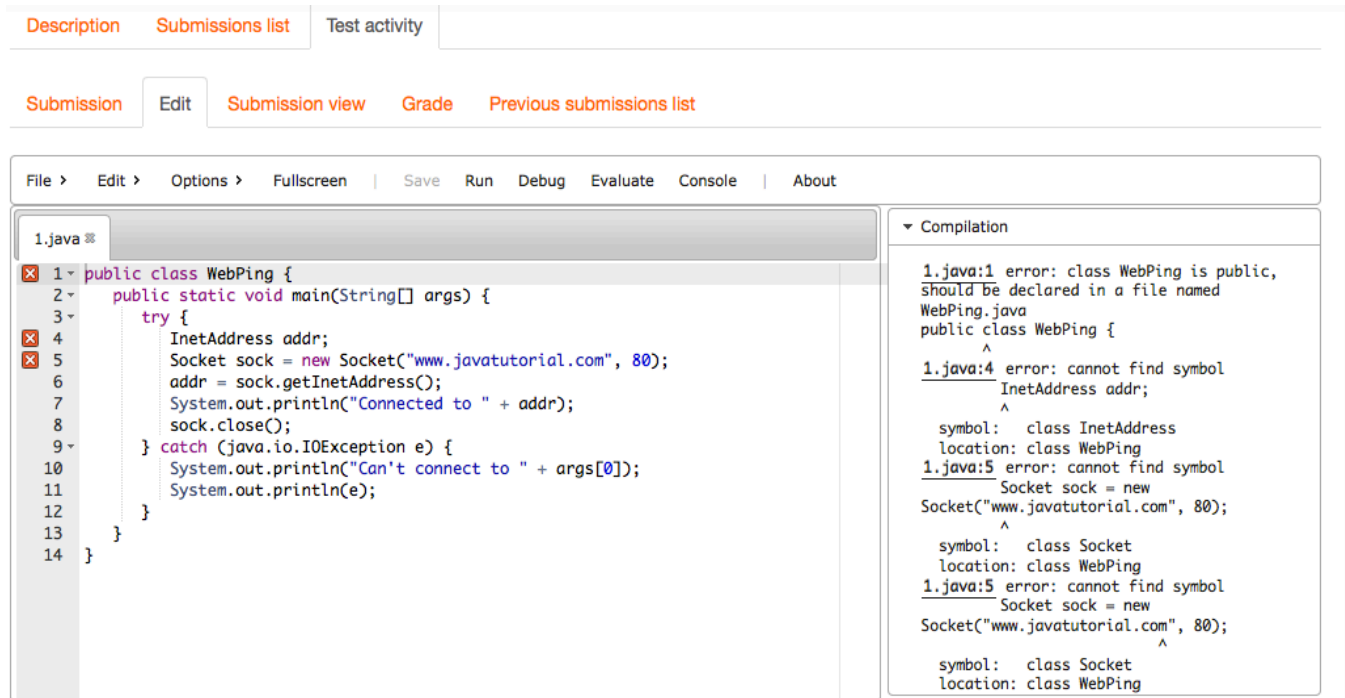


Fig 4.3: Screenshots of program codes in the virtual lab

The lecturer on the other hand, executes and tests the submissions in the virtual lab and provides students with feedbacks using forum and chats that formed the contents. The contents generated include forum and chats about the virtual lab activities where the students interact among themselves and with the course lecturer. Presented below are snapshots of the forum and chats contents (see full snapshots/data presented in Appendices F and G), details are analysed in sections 4.4.2.1 and 4.4.4.2.2

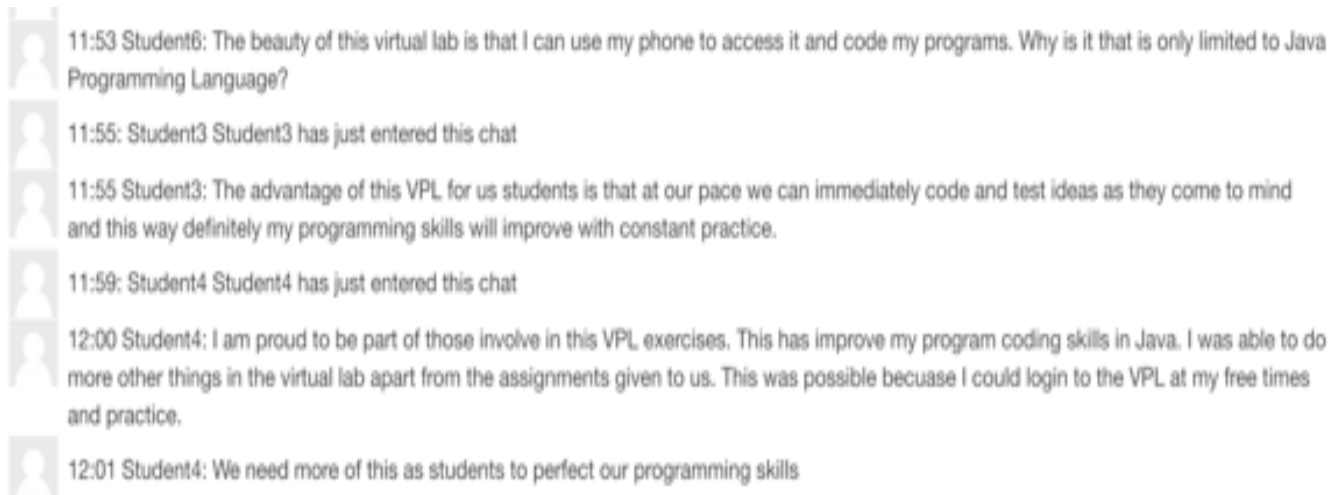


Fig 4.4: Chats Content Snapshot

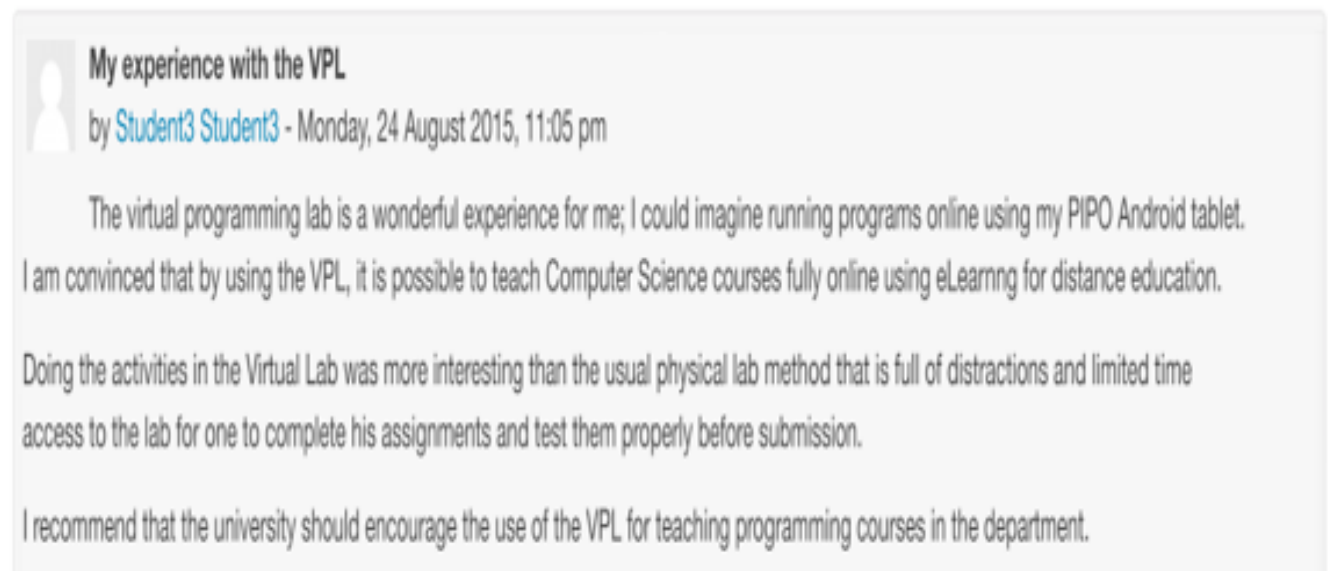


Fig 4.5: Forum Content Snapshot

### 4.3 Data Analysis

Data analysis is a process that involves developing responses or answers to questions' items (in this research context - interview questions) and also examination of data in form of contents (Clarke, & Braun, 2014). Common steps in this process include identifying issues, shedding light on relevant issues (to provide clear understanding of the

responses and pointing on the data quality), and determining the availability of suitable data (Clarke, & Braun, 2014).

Often a picture may be worth a thousand words (Mäkynen, 2012); thus, the data collected by each instrument of this research work were explored, visualized and analysed using the theoretical framework as follows.

### 4.3.1 Analysis of Interviews

The research interview was in two parts, that is, the interview with the lecturer and the interview with the participating students. The interviews source materials were imported into Nvivo and transcribed. The transcriptions were later explored and visualised for existence of patterns that metamorphoses into themes (coded into Nvivo’s nodes for analysis).

#### 4.3.1.1 Students’ Interview

The students’ interviews were transcribed using Nvivo, and the transcription was queried using Nvivo ‘Text Search’ tool while the search results were visualized using word trees as presented below with more in Appendix H.

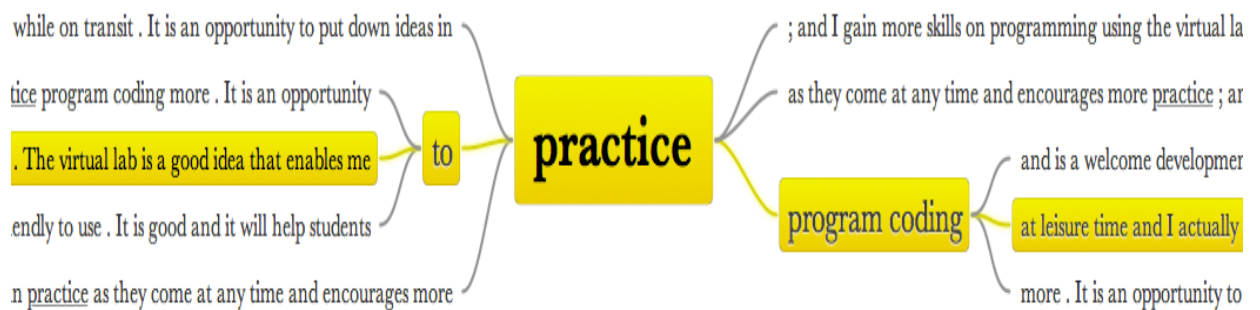


Fig 4.6 Visualised Students’ Interview Data

The statement *'The virtual lab is a good idea that enable me to practice program coding at leisure time ...'* on the word tree indicates that the activity community can access and used the artifacts to practice programming at their leisure time; thereby engaging the learners into performing actions on the activity's object using the artifacts. This shows that the virtual lab activity system do not have defined timeframe or access restriction to the lab as common with physical labs, and it also promotes self-practice.



Fig 4.7 Visualised Students' Interview Data

Also, the statement *'Using the virtual lab enable me to practice a lot of things on my own apart from the exercise given ...'* on the above word tree shows that the socio-cultural changed of the artifact mediates the subjects' actions on the activity object. That is, the change from physical lab to virtual lab environment helps students to do more hands-on programming activities; which can enhance their programming knowledge and skills.

The activity system subjects' (students) interviews data was coded into the following major themes for easy filtering, grouping, and

interpretation of the subjects' views and experiences using the artifacts to perform actions on the activity object.

### **Programming Practice**

This theme's node contains eight (8) sources as displayed on the snapshots below.

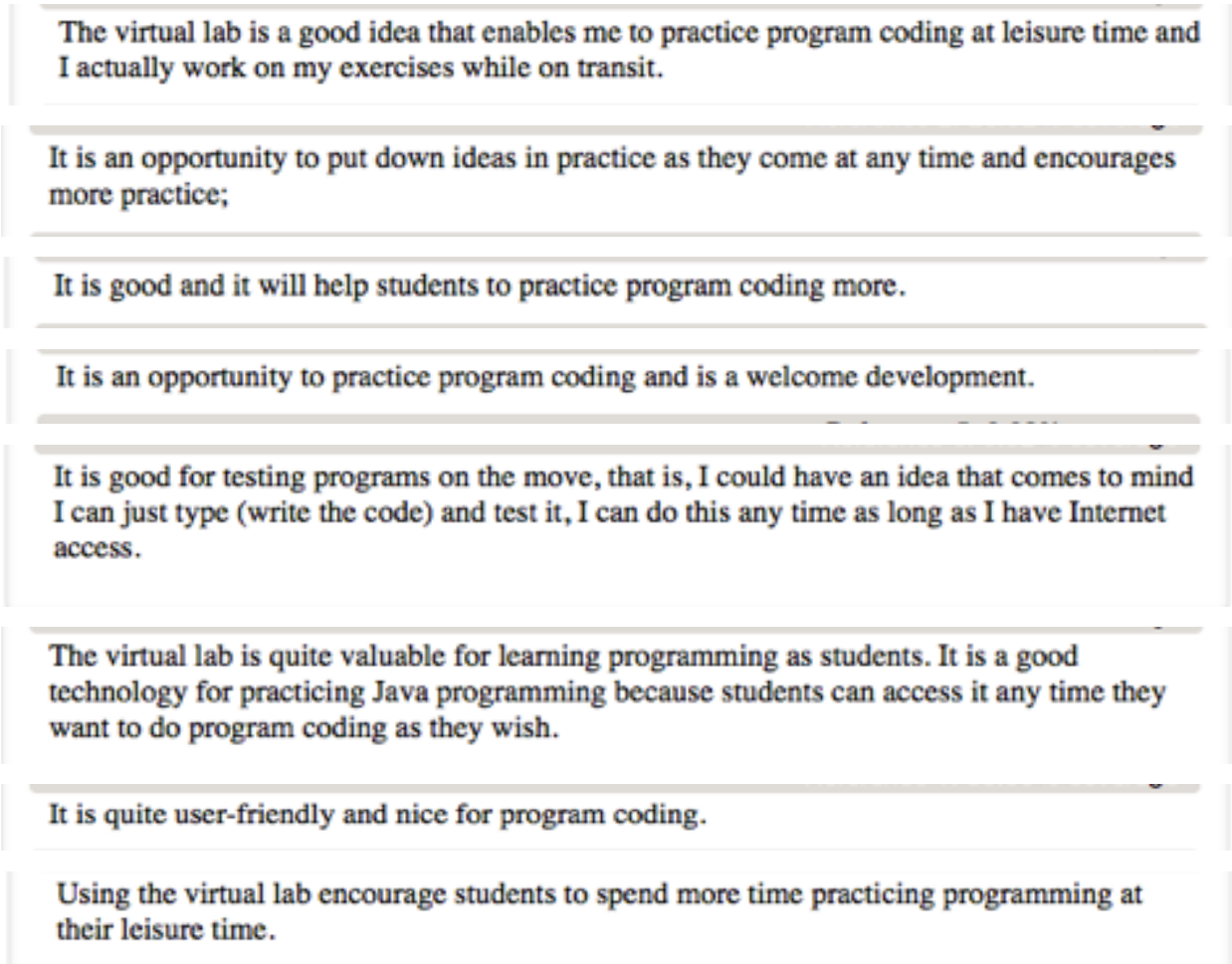


Fig 4.8 Programming Practice Theme Elements (Students Interview)

The first five sources (e.g. '*...enables me to practice program coding at leisure time and I actually work on my exercises while on transit*', '*...It is an opportunity to put down ideas in practice as they come at any time and encourages more practice...*') indicated that the virtual

lab provides students with opportunity and enabling environment to practice programming. This shows that unlike the physical lab with constraints of limited access time and inadequate computers for the learners; the virtual lab provides students with environment for hands-on programming practice.

The subjects accessed the virtual lab using their devices (private computers and mobile devices) from home, hostels, and at hotspots. This was possible with the virtual lab because the activity system rules and regulations (e.g. access the virtual lab with login details, access the virtual lab anywhere with network connection) enable the subjects' participation within the activity system community. These rules also provide procedures for acceptable interactions among the community members (Leonardo, & Manning, 2017). Therefore, this aligned with the activity theory-based framework in fig 2.7 and the corresponding activity system shown in fig 2.8.

As mentioned in table 3.1, this interviews result answered the first research subsidiary question (*'What is the objective of the virtual lab programming?'*), that is, the objective of the virtual lab is to provide students with a lab environment to practice programming. Therefore, students can leverage on the access affordances of the virtual lab to practice programming as maintained by Lewis, (2014).

Also, the three last sources (e.g. *'...is quite valuable for learning programming as students'*, *'it is quite user-friendly and nice for program coding.'* *'... a good technology for practicing Java programming...'*) revealed that the virtual lab is a valuable mediating tool, an enabler for learning and practicing programming.

Viewing this with AT lens, the subjects (the lecturer and students) performed actions on the activity many times using artifacts (with mediation function), and the object (Java programming) is being transformed several times into a stable finished product or outcome (programming skills acquired). This finding shows that the virtual lab provide an alternative lab environment for students programming practice, this agreed with (Bose, 2013; Pellas, et al, 2017) that the virtual lab has rich educational features for teaching and learning practical concepts.

### **Practical Programming Skills**

The node of this theme contained five (5) sources as shown below on the node's snapshots.

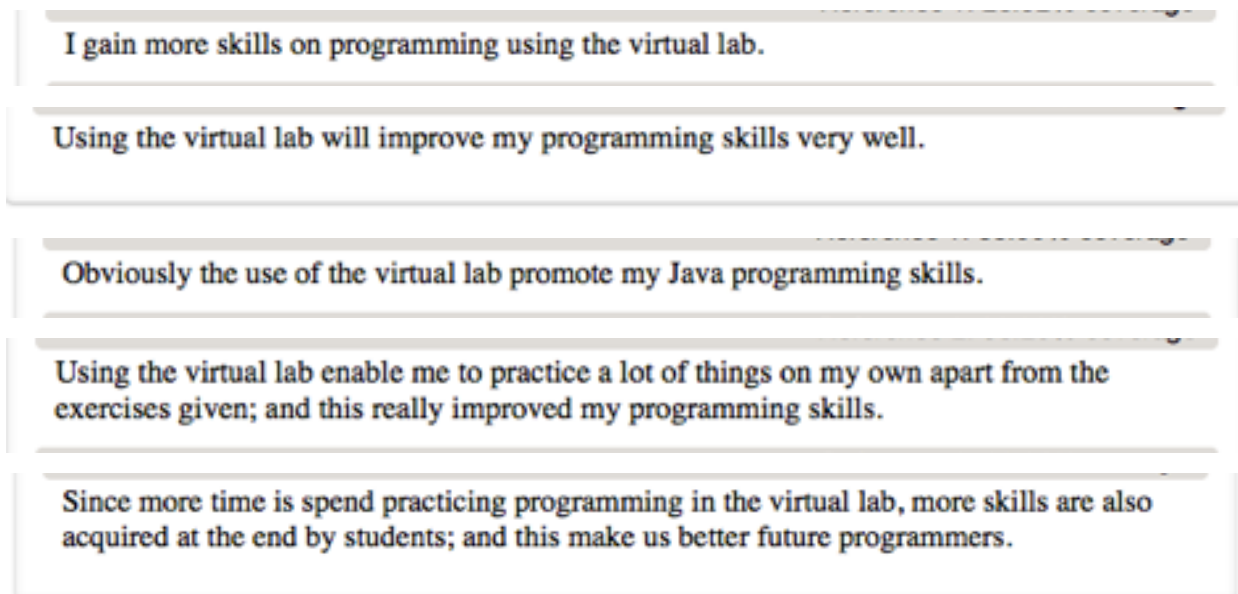


Figure 4.9 Practical Programming Skills Theme Elements (Students Interview)

All the five sources in this node indicated that use of the virtual lab promote and enhance students' practical programming skills (e.g. *'I gain more skills on programming using the virtual lab'*, *'Using the*

*virtual lab will improve my programming skills very well*). The virtual lab enables students to spend more time practicing program coding on their own (e.g. *‘using the virtual lab enable me to practice a lot of things on my own...’*). As noted in the last source (e.g. *‘...and this make us better future programmers’*), is it and illustration that use of virtual lab can mediate students programming skills acquisition.

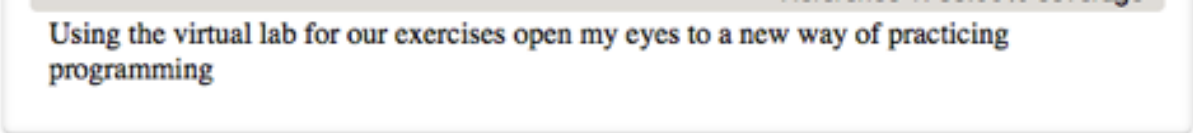
Learning can occur through subjects’ (participants) collective activities in the virtual lab that is performed around the object (i.e. Java programming) of the activity system (Leonardo, & Manning, 2017).

Also, the activity outcome is the result or consequences faced by the subject(s) based on their actions driven by the activity object, which could motivate, encourage or discourage the subjects from participating in future activities (Bravo Olavarria, 2013). Thus, from the source statement: *‘... virtual lab enables me to practice a lot of things on my own...’* it shows that the outcome or consequences of the subjects’ actions driven by the object is encouraging since the participants can practice more on their own. This findings shows that use of virtual lab can enhance students’ practical programming skills, this concurred with Mahajan, Kulkarni, & Diwakar, (2016) findings.

### **Pedagogical Change**

This theme’s node contained two (2) sources as shown below.

It is good for testing programs on the move, that is, I could have an idea that comes to mind I can just type (write the code) and test it, I can do this any time as long as I have Internet access.



Using the virtual lab for our exercises open my eyes to a new way of practicing programming

Figure 4.10 Pedagogical Change Theme Elements (Students Interview)

From the sources in this theme's node, it shows that the pedagogical learning approach of the students changed (e.g. ... *'open my eyes to new way of practicing programming'*) as they experiment with the virtual lab to practice Java programming. The virtual lab provides the students with independent environment to learn program coding at their own pace, as expressed in respondent's statement: (*'...good for testing programs on the move...'*). Hence, this result shows that the virtual lab promotes student-centred learning approach in conducting practical programming classes; and this answered the third subsidiary research question (i.e. *'What are the teaching and learning practices evident in the virtual lab?'*)

According to Leontiev, the object (Java programming) is key in directing the activity (hands-on Java programming), while the subjects' actions (program coding, testing, debugging) changed the activity system's object in reaction or response to motives within the activity system (Engeström, 2017b; Bravo Olavarria, 2013). These subjects' actions on the object (Java programming) can transform the motives into outcomes as shown on fig 2.8 in section 2.5. From the data (e.g. *'... open my eyes to new way of practicing programming'*) in fig 4.10, it can be observed that the virtual lab activities also changed the participants' pedagogical approach on hands-on

programming as asserted by (Encalada, & Sequera, (2017; Dunn, (2017).

### **Scaffolding**

This theme's node contains two (2) sources as displayed on the snapshots below.

Using the virtual lab for our exercises open my eyes to a new way of practicing programming and the instant feedback from the lecturer help me to correct my mistakes.

It was very clear that using the virtual lab for our practical classes, we were able to gets our lecturer attention more

Figure 4.11 Scaffolding Theme Elements (Students Interview)

The two sources shows that the virtual lab present a seamless environment for the educator or lecturer to scaffold on the students' hands-on Java programming learning process by providing the students with instant feedback on their programming exercises (e.g. '*...the instant feedback from the lecturer help me to correct my mistakes*'). The activity system rules enable the subjects (lecturer and students) to interact and communicate as members of the activity community, each participating based on the division of labour using artifacts (with meditation function). These interactions and communications enable the lecturer to scaffold the students' activities and provide them with feedbacks; hence, this aligned with the analytical framework on fig. 2.7 in section 2.5.

Working in the virtual lab unlike the traditional physical lab, the lecturer can either synchronously or asynchronously guide and coach each student (e.g. '*... we were able to gets our lecturer attention more...* '); and this can encourage the students to do more.

Also, from the context of CHAT, artifacts are described as cultural tools with meditational function, which can be determine based on local and historical position or context that help participants of an activity system to carry out an activity (Bozalek et al., 2015; Bravo Olavarria, 2013; Leonardo, & Manning, 2017). This result shows that the virtual lab is a cultural tool that helps participant (lecturer) to carry out an activity of guiding and coaching students either synchronously or asynchronously, this concurred with Farooq, & Khlad, (2013); Hovardas, Xenofontos, & Zacharia, (2017).

### **Student Engagement**

The ‘student engagement’ theme’s node contains three (3) sources as displayed on the snapshots below.

The virtual lab is a good idea that enables me to practice program coding at leisure time and I actually work on my exercises while on transit.

Using the virtual lab enable me to practice a lot of things on my own apart from the exercises given; and this really improved my programming skills.

The virtual lab is very interesting because I can use it to learn programming on my own.

Figure 4.12 Student Engagement Theme Elements (Students Interview)

These three sources indicated that the virtual lab engages students into self-paced program coding practice (e.g. ‘...*I can use it to learn programming on my own...*’, ‘... *enable me to practice program coding at leisure time...*’). Thus, it is observed that the learners get engaged with hands-on programming learning process through self-motivation and determination. On the other hand, using the virtual lab

for hands-on programming practice stimulates self-motivation and determination in students.

The activity outcome encourages the subjects (students) to participate in further activities (Bravo Olavarria, 2013). Therefore, the self-motivation and determination of the subjects to practice and engaged with hands-on programming was enhanced by the activity outcome. The finding here shows that using virtual lab for hands-on programming teaching and learning engages the learners into self-practice, which can mediate their programming skills acquisition.

### **Virtual Lab Accessibility**

This theme's node contains seven (7) sources as displayed on the snapshots below.

The virtual lab was very easy to access; however there was a network challenge i.e. the Internet connection.

The virtual lab was easy to access, however there was network problem.

The virtual lab was quite easy to access by typing in my login details then instantly I was able to access the VPL environment.

Accessing the virtual lab for my Java programming activities was very easy because connecting to the virtual lab was achieved even with my mobile device.

I was able to access the virtual lab easily each time I want to use it to do my exercises or practice program coding.

The virtual programming lab was accessible all the time and anywhere that a choose to use it to practice programming.

I prayed that may the department allow us to continue to use this virtual programming lab for all our programming courses so that we can have more time for hands-on programming practice.

Figure 4.13 Virtual Lab Accessibility Theme Elements (Students Interview)

The first three sources (e.g. “*The virtual lab was very easy to access...*”, “*The virtual lab was easy to access...*”, “*The virtual lab was quite easy to access...*”) all indicated that the virtual lab was accessible as long as one has permission or login details. It is observed that this could be the motivating factor that stimulates the students to practice hands-on programming. However, the first and second sources also showed that the students encountered Internet connection problem, but they were not discouraged.

The fourth, fifth and sixth sources also indicated that the virtual lab was accessible even with their mobile devices to practice program coding or to do their hands-on programming assignments. The seventh source shows that using virtual lab implies easy access to lab, and more time for students to undertake hands-on programming practice. Examining these using AT lens, it shows that the artifact (virtual lab) mediates the subjects’ access to a lab environment to carry out hands-on programming activities. This finding shows that the mediational function of the virtual lab enables the students to access lab environment using their private devices remotely and at their own pace (Lewis, 2014). Thus, the virtual lab as an artifact mediates the challenge of policy against BYOT.

### **Virtual Lab Recommendation**

This theme’s node contains four (4) sources as shown on the snapshots below.

**I preferred and recommend the virtual lab because it can be access anywhere anytime compare to the traditional lab where every student has to come to the lab.**

I will like the department to make sure all our lecturers use the virtual programming lab to teach all our courses. And the university should help the department to achieve this.

I will really urge the University and the department to take this very seriously to go beyond just one programming language (i.e. it should not be limited to only Java programming language) to cover all the programming languages they are teaching in the computer science and that will be the major advantage.

It was very clear that using the virtual lab for our practical classes, we were able to get our lecturer attention more, so I recommend the adoption of this important concept.

Figure 4.14 Virtual Lab Recommendation Theme Elements (Students Interview)

The first source of this theme (e.g. *'I preferred and recommend the virtual lab because it can be access anywhere anytime ...'*) recommended the use of the virtual lab because of its accessibility affordance in terms of time and place of access. This shows that the recommendation is influenced by the activity system artifact (virtual lab) ability to mediate the problem of computer lab access and the resistance to BYOT policy. In the second, third, and fourth sources (e.g. *'I will like the department to make sure all our lecturers use the virtual programming lab to teach all our courses'*, *'I will really urge the university and the department to take this very seriously to go beyond just one programming language'*, *'... I recommend the adoption of this important concept'*), the students recommended the use of virtual lab to the entire university and the Computer Science department for all the lecturers to embrace and adopt it use in teaching all programming languages offered in the department.

This shows that the result of the actions performed by the activity system community on the activity object transformed the subjects' (students) pedagogical thought to learning practical programming. Also, the activity system outcome encourages the subjects to participate in future activities (Bravo Olavarria, 2013) using the virtual lab. Hence, they recommend the activity system for all programming courses. Therefore, this result demonstrated that the virtual lab intervention in Java programming language practical classes was actually worthwhile and a welcome development.

### **Virtual Lab Usability**

This theme's node contains five (5) sources as shown on the snapshots below.

The virtual lab was very easy to use.

The virtual lab was easy and friendly to use.

Using the virtual lab was amazingly easy to use; at the begging I thought it would be difficult to us.

Using the virtual lab was easy for me to write programs and test them.

Using the virtual lab is as easy as using Facebook. There was no difference writing and running programs inside the virtual lab and doing same in our usual computer lab

Fig 4.15 Virtual Lab Usability Theme Elements (Students Interview)

All the five sources in this theme showed that the virtual lab as a tool is quite friendly and easy to use even as a 'first-timer'. It is also evident that there was a fear or concern among the participating students on how to use the virtual lab to conduct practical

programming activities. But after using the virtual lab, the anxiety changed as indicated by the statement ‘... *the virtual lab was amazingly easy to use...*’ in fig 4.15. In the context of CHAT, the activity system rules guide and direct subjects’ participation and actions within the activity system community when performing the activity to realized or achieved the object (Bravo Olavarria, 2013; Leonardo, & Manning, 2017). Therefore, the rules of the activity system enhanced the subjects’ participation and actions within the community, making it easy to participate and act based on the division of labour in the activity system.

The last source remarkably shows that the students find the use of virtual lab for practical classes to be ‘learning in their context’ i.e. “*using the virtual lab is as easy as using facebook*”.

CHAT theorists maintained that social participation and interaction in an activity could be changed dynamically when the social and cultural conditions changed (Wilson, 2014; Bravo Olavarria, 2013). Therefore, the statement ‘*Using the virtual lab is as easy as using Facebook*’ in fig 4.15 indicates that the subjects’ (students) participation in the hands-on programming activity changed when the social and cultural conditions change (i.e. lab tools change to virtual lab) in favour of their context. This finding shows that the virtual lab is usable for hands-on programming practice and user-friendly.

### **Virtual Lab Usefulness**

The ‘virtual lab usefulness’ theme’s node contains three (3) sources as shown on the snapshots below.

Use of the virtual lab is a good development for us students because we don't need to assemble ourselves in a computer lab with few computers that cannot even go round all students.

Using the virtual lab will also save cost for the university in buying expensive computers to equip labs.

The virtual lab is good for our large classes because we students can work independently in the virtual lab without queuing for computers to use.

Fig 4.16 Virtual Lab Usefulness Theme Elements (Students Interview)

The first and third sources show that the virtual lab is useful for conducting practical programming lessons in a large class size; and in the context of Computer Science department of UniJos where there are limited number of computers in the lab for all students to use concurrently. The second source illustrates the cost-saving usefulness of the virtual lab in an institution like UniJos where budget line or purchasing power is not adequate to get all required computers and related accessories in a physical lab for hands-on practical programming purposes.

These implied that, the artifact (virtual lab) apart from mediating the computer lab access and BYOT policy challenges, it can also mediate and mitigate the problem of limited number of computers in physical lab as indicated by the statements '*The virtual lab is good for our large classes because we students can work independently in the virtual lab without queuing for computers to use.*' and '*Using the virtual lab will also save cost for the university in buying expensive computers to equip labs*' in fig 4.16 above. This finding demonstrated that the virtual lab could be useful for practical programming classes

with large students size and also in a situation where there are limited computer facilities in traditional lab. This agreed with Hovardas, Xenofontos, & Zacharia, (2017) statement that virtual lab enables many students to interact with it at the same time without any impact on its performance and functionality.

### **Virtual Lab Compare to Traditional Lab**

This theme's node contains five (5) sources as shown on the snapshots below.

I prefer the virtual lab environment to the traditional lab because in virtual lab I am at ease unlike the tension attached to the normal traditional lab and in virtual lab environment I express myself better.

I preferred and recommend the virtual lab because it can be access anywhere anytime compare to the traditional lab where every student has to come to the lab.

I definitely preferred the VPL because of easy accessibility, and issue of having hardware (computers in a traditional lab) is a problem, while with VPL either with a phone or any capable device I can have access to a full programming compiler (environment) that I can find my programs.

Cost-wise the VPL is very cost-effective because we will not have individual system to serve individual students; students can bring their systems not necessarily computer systems but their tablets or cell phones.

The virtual programming lab is far far better than our computer lab because not all students will get a computer in our lab to use at the same time but virtual lab can be access by many students at the same time.

Fig 4.17 Virtual Lab Compare to Traditional Lab Theme Elements (Students Interview)

The virtual lab is preferred to traditional lab in the first source because it does allow quiet students to expressed themselves virtually and work without tension or nervousness. This shows that the interactions and communications between the activity system

community members in the virtual lab enable students to expressed themselves while participating and performing their actions following the community division of labour as indicated by the statement ‘... *in virtual lab environment I express myself better.*’ The second source indicates that the virtual lab is preferred to traditional lab because of its accessibility.

The third and fourth sources showed students’ preference for virtual lab over traditional lab because of affordances of the virtual lab in terms of cost and its affordance to be accessed using mobile devices. Similarly, as indicated in the last source, the virtual lab can enable many students to access and use it at the same time unlike physical lab where students have to queue for computers to use for their hands-on practical activities.

The statements: ‘*I definitely preferred the VPL because of easy accessibility ...*’, ‘*While with VPL either with a phone or any capable device I can have access to a full programming compiler ...*’, and ‘... *but virtual lab can be access by many students at the same time.*’ in fig 4.17 are indications that the activity system artifacts (virtual lab, mobile devices) have the mediation function to mediates access to lab environment and the challenge of limited number of computers in a physical lab. This finding shows that the students preferred the virtual lab to traditional or physical lab because virtual lab is accessible remotely, compatible with mobiles devices, and interactive.

## **VL Perception**

This theme’s node contains eight (8) sources as shown on the snapshots below.

The virtual lab is a good idea that enables me to practice program coding at leisure time

It is an opportunity to practice program coding and is a welcome development.

It is quite user-friendly and nice for program coding.

The virtual lab is very friendly but I will also like to add that there may be a few limitations that I notice like not having the full compiler as on desktop.

The virtual lab experience was a wonderful one that I wish to use the virtual lab for all my programming courses in the department.

The experience was a nice one. Each time I use the virtual lab, I feel as if the lab is on my laptop not being remote.

The virtual lab is very interesting because I can use it to learn programming on my own.

If we can use the virtual lab throughout to our final year, I am very sure all of us will be gurus in programming because our lecturers will find it easy to advice and guide us in the virtual lab.

Fig 4.18 VL Perception Theme Elements (Students Interview)

In the first four and the last sources, the virtual lab was perceived as *interesting*, *user-friendly*, *a good idea* and *a welcome development* that provides opportunity to practice program coding at leisure. The fifth and sixth sources show how the students assessed the virtual lab experience as *wonderful* and *nice* because using it was seamless. The perception of the virtual lab in the seventh source deduced that using the virtual lab environment for hands-on practical programming classes can give the lecturers better opportunity to scaffold on the students' practical programming learning process; and hence, nurture the students to be skilled programmers.

From socio-cultural perspectives of Vygotsky, Leontiev, and Engeström, humans learn by doing, act collectively and communicate through their actions; they create, use and adopt relevant tools in the process (Wilson, 2014; Taylor, 2014; Behrend, 2014). Therefore, these perceptions of the artifact (virtual lab) by the students could be because of their ability to learn by doing, communicates through their actions, and wishes to adopt the tool (virtual lab), as evident in fig 4.18 i.e. *‘It is quite user-friendly and nice for program coding.’ ‘The virtual lab experience was a wonderful one ... I wish to use the virtual lab for all my programming courses ...’*. Hence, the findings revealed students’ positive perception of the virtual lab for hands-on practical programming practice.

#### 4.3.1.2 Lecturer’s Interview

The lecturer’s interview was transcribed using Nvivo, and the transcription was queried using Nvivo ‘Text Search’ while the search results were visualized using word trees as presented below with more in Appendix I.

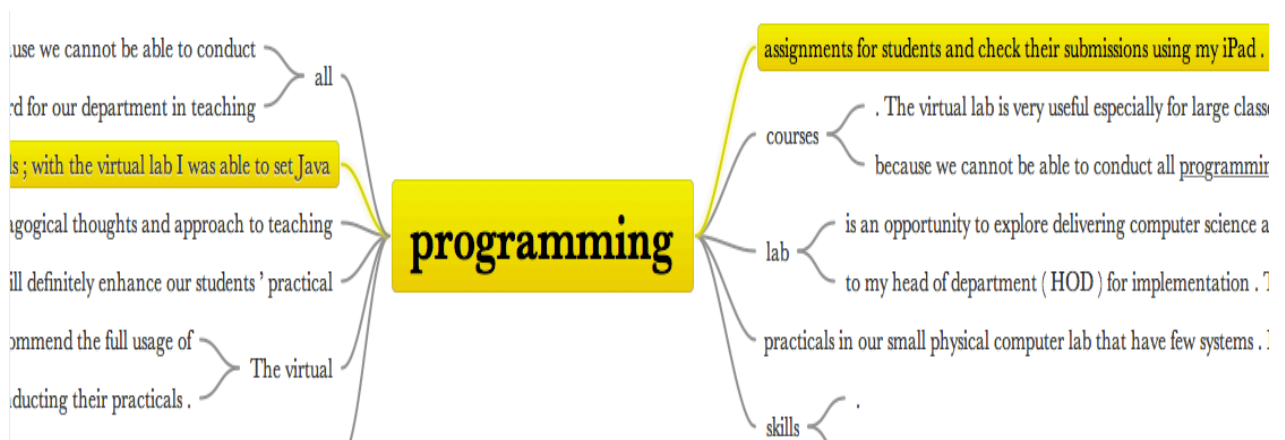


Fig 4.19 Visualised Lecturer’s Interview Data

The highlighted texts i.e. ‘... with the virtual lab I was able to set Java programming assignments for students and check their submissions using my iPad’ shows that the subject (lecturer) uses the activity system artifacts (iPad, virtual lab) to mediate learners’ acquisition of scientific knowledge (Java programming).

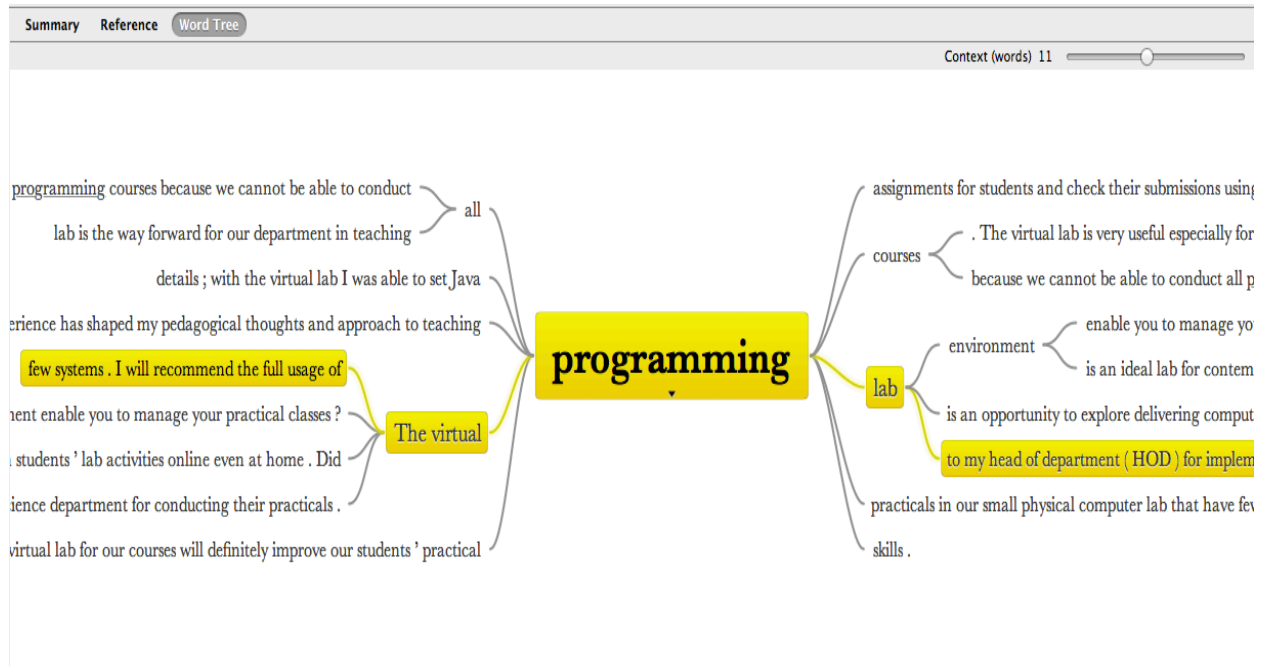


Fig 4.20 Visualised Lecturer’s Interview Data

The above highlighted text i.e. ‘... I will recommend the full usage of the virtual programming lab to my head of department (HOD) for implementation ...’ revealed that the artifact (virtual lab) have the affordances to mediate learners’ hands-on programming skills.

The transcribed lecturer’s interview was also coded into themes for easy grouping, filtering, and interpretation of the lecturer’s views and experiences with the virtual lab programming activities. Each of the themes are represented and interpreted as follows:

### Scaffolding

This theme's node contains four (4) coded sources from the lecturer's interview transcription as shown on the snapshots below.

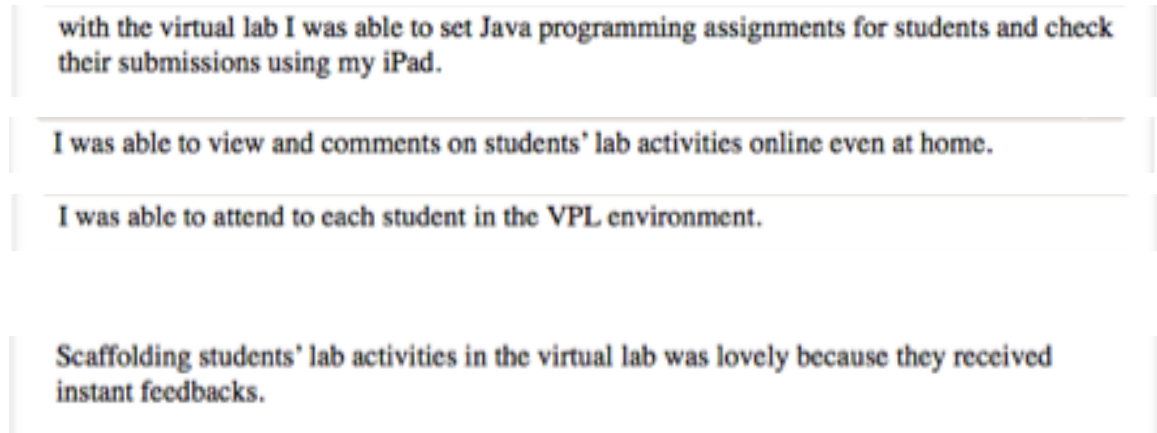


Fig 4.21 Scaffolding Theme Elements (Lecturer Interview)

The first and second sources show that the lecturer was able to access the virtual lab using his iPad to assigned tasks and scaffolds on the students' Java practical programming activities by making comments and perusing their lab activities online even at home. This is evident in fig 4.21 as indicated by the statements: '*... I was able to set Java programming assignments for students and check their submissions using my iPad*', '*I was able to view and comments on students' lab activities online even at home.*'

The educator's experience with the virtual lab as shared in the third and fourth sources is an affirmation that the virtual lab environment encourages and promotes instant feedbacks on learners' activities. Also, the virtual lab provides a convenient platform to attend to students with their practical programming tasks. This aligned with the analytical framework on fig 2.7 in section 2.5.

There exist a division of labour in the activity system community, in which each subject (e.g. lecturer – assign and scaffolds tasks) or subjects (e.g. students – perform tasks) have particular actions to be perform on the activity (Bozalek et al., 2015; Leonardo, & Manning, 2017) as shown in the respondent’s statement: *‘I was able to attend to each student in the VPL environment’*. Therefore, this finding shows that the hands-on programming activity system division of labour enables the students to carry out programming tasks while the lecturer played his role as educator using the virtual lab as a mediating tool. Hence, the virtual lab environment enables the lecturer to mediate on the students’ hands-on programming learning processes as illustrated on fig 2.8 in section 2.5.

### **Class Management**

This theme’s node contains two (2) sources as shown on the snapshots below.

The virtual programming lab environment is an ideal lab for contemporary program coding teaching and learning because assisting learners in the virtual lab environment is much easier for a large class compare to normal lab.

The virtual lab is very useful especially for large classes and for teaching computer age students who like self-pace and independent practice.

Fig 4.22 Class Management Theme Elements (Lecturer Interview)

The first source of this theme revealed that it was easy to managed students’ activities in the virtual lab. Thus, using the virtual lab as a programming lab artifact, its enable the educator to played his role of class management online. This help the lecturer to mediates on the students’ hands-on programming learning processes. It also shows that

the virtual lab could be a good option or alternative to handle large class size practical sessions as expressed by the subject in the statement: ‘... *assisting learners in the virtual lab environment is much easier for a large class ...*’

Similarly, the second source shows how useful is the virtual lab for conducting hands-on programming activities with large class size, that is, ‘... *virtual lab is very useful especially for large classes ...*’ This also indicates that the virtual lab have features that could enhance managing and teaching hands-on programming in contemporary learners’ context. From AT theorist’s perspective, the tools are social, cultural-historic material resources or artifacts that the subjects used to achieved the object (Wilson, 2014). Therefore, this finding revealed that the virtual lab is a social, cultural-historic resource that the lecturer could used to conduct and managed students’ hands-on programming sessions.

### **Pedagogical Change**

The ‘pedagogical change’ theme’s node contains three (3) sources as shown on the node snapshots below.

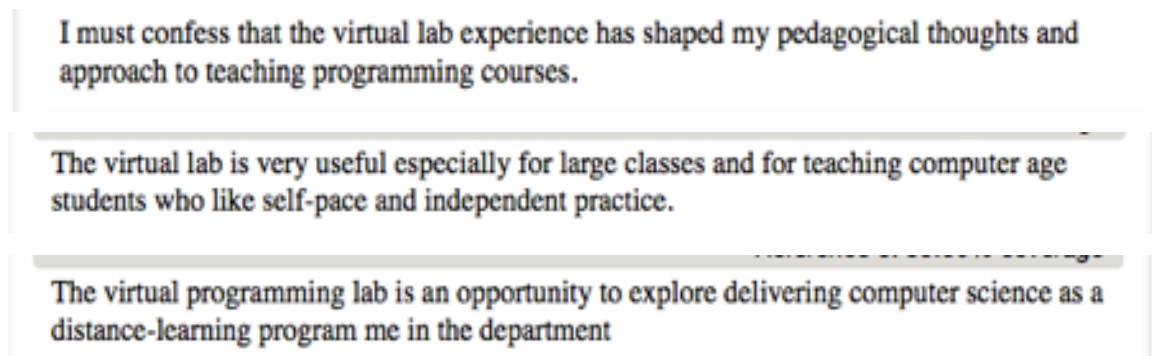


Fig 4.23 Pedagogical Change Theme Elements (Lecturer Interview)

The first source shows that the lecturer’s experience with the virtual lab programming activity system have changed his approach towards

teaching programming courses. This could possibly influence him to adopt the virtual lab for teaching his programming courses. The second source indicates that the lecturer viewed the virtual lab as a tool that could promote and support students' self-pace and independent programming practices. The third source shows that the virtual lab could be use to support delivering computer science courses as distance-learning programme. Thus, the virtual lab provides the opportunity to handle practical programming sessions online for eLearning programming courses.

The subject's motives for participating in the activity were contradictions or tensions in the activity system (Engeström, 2017b; Bravo Olavarria, 2013), which could make the activity system unstable. But when the subjects' actions changed or transformed the activity system's object in reaction or response to these contradictions or tensions, the motives also changed making the activity system stable. This is in line with the activity theory-based analytical framework shown in fig 2.7 and the activity system illustrated in fig 2.8.

Therefore, the lecturer's statement: *'I must confess that the virtual lab experience has shaped my pedagogical thoughts and approach to teaching programming courses'* was due to the transformation of the activity system object. Hence, CHAT can help a researcher to understand, analyse and explain the relationship between participants' thoughts, feelings and the activity they are doing using cultural resources or artifacts (Wilson, 2014; Bozalek et al., 2015). This finding illustrates that the educator's experience with the virtual lab environment for conducting practical programming sessions has changed his pedagogical

thoughts and approach on how to conduct practical programming classes.

### **Virtual Lab Recommendation**

This theme's node contains three (3) sources as shown on the snapshots below.

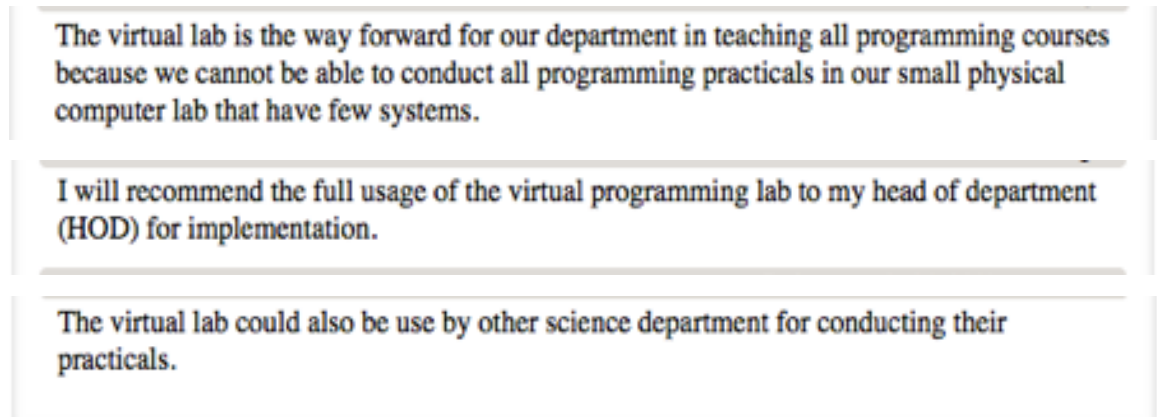


Fig 4.24 Virtual Lab Recommendation Theme Elements (Lecturer Interview)

In the first and second sources, the educator recommends the implementation and full usage of virtual lab environment as alternative way forward for conducting all hands-on programming activities in the computer science department. These recommendations aligned with the first research benefit stated in section 1.5 above i.e. *'to provide alternative computer lab engagement'*. Similarly, in the last source, the virtual lab is recommended for all science departments to enhance their practical classes.

Analysing this using AT, it shows that the artifact (virtual lab) have the mediation function to mediates the problems of limited number of computers in the physical lab and the BYOT policy. This is shown in the respondent's statement: *'... virtual lab is the way forward for our department in teaching all programming courses because we cannot be*

able to conduct all programming practical in our small physical computer lab that have few systems' (see the snapshots in fig 4.24). Also, the virtual lab could be explored for other practical activity systems; apart from the programming activity system in UniJos as stated by the lecturer '*... virtual lab could also be use by other science departments for conducting their practical*'. Hence, the findings here underpinned use of virtual lab as alternative to physical lab for programming classes and other science related practical activities in the University.

### 4.3.2 Analysis of the Activity System Contents Generated

The interactions of the activity community members within the activity system generated contents in form of chats and forum. These contents were explored, visualized, coded into themes and each were analysed as follows.

#### 4.3.2.1 Chats Content

The chats content was queried using Nvivo 'Text Search' and the search results were visualized as shown below (see more in Appendix K).

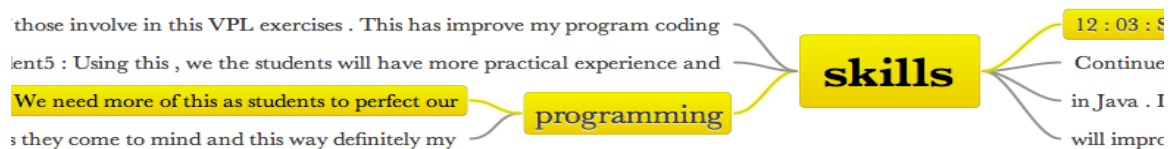


Fig 4.25 Visualised Activity System Chats Content

The text highlighted: *‘We need more of this as students to perfect our programming skills ...’* in the above word tree shows that the subjects’ actions on the activity object within the community, guided by the activity system rules resulted into encouragement for hands-on programming practice. Such encouragement when sustained, it could help mediate learners’ acquisition of programming skills.

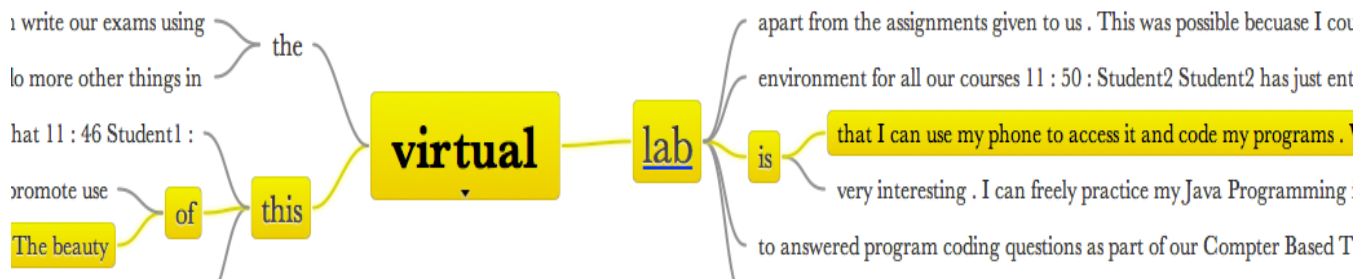


Fig 4.26 Visualised Activity System Chats Content

The respondent’s statement: *‘The beauty of this virtual lab is that I can use my phone to access it and code my programs ...’* in this second word tree indicates that the virtual lab can be access using mobile phone, which students have high affinity to its use. Hence this could also be a motivation to encourage students into practicing programming at their pace.

The chats content was coded into the following major themes, which enhanced filtering, categorization, and analysis of respondents’ views and experiences with the virtual lab programming activities.

### Interest in Using VL

This theme’s node contained four (4) sources as shown below.

- This virtual lab is very interesting.
- I love if the department could fully implement it,

he beauty of this virtual lab is that I can use my phone to access it and code my programs.

Why is it that is only limited to Java Programming Language?

Fig 4.27 Interest in Using VL, Theme Elements (Chats Content)

The first source shows how the respondent was interested in using the virtual lab environment for hands-on programming practice. In the second source, the respondent wishes for continuous use of the virtual lab. This is an indication of interest for the use of virtual lab after exploring it with practical programming activities. Also, the interest expressed in the forth source imply that the participant is willing to use the virtual lab for all their programming courses in the department.

It is cleared from the third source of this theme that the participant is interested in using the virtual lab for their programming activities because its gives them the opportunity to access the lab, do their assignments and practice program coding using their mobile devices. As outline on the analytical framework in fig 2.7, the tools enable the participants to performed tasks.

As earlier analysed under the interviews in sections 4.3.1.1 and 4.3.1.2, the outcome of the activity system, which is the consequences faced by the subjects based on their actions driven by the activity object, have encouraged the subjects to be interested and wishes to participate in future programming activities using the virtual lab (Bravo Olavarria, 2013). This is evident in the respondents' statements: '*This virtual lab is very interesting*'; '*... beauty of this virtual lab is that I can use my phone to access it and code my programs.*' '*Why is it that is limited to only Java Programming Language?*' This finding shows that the respondents

were interested in the activity system using virtual lab as programming lab environment.

### **Programming Practice**

The ‘programming practice’ theme contains four (4) sources as shown in the node snapshots below.

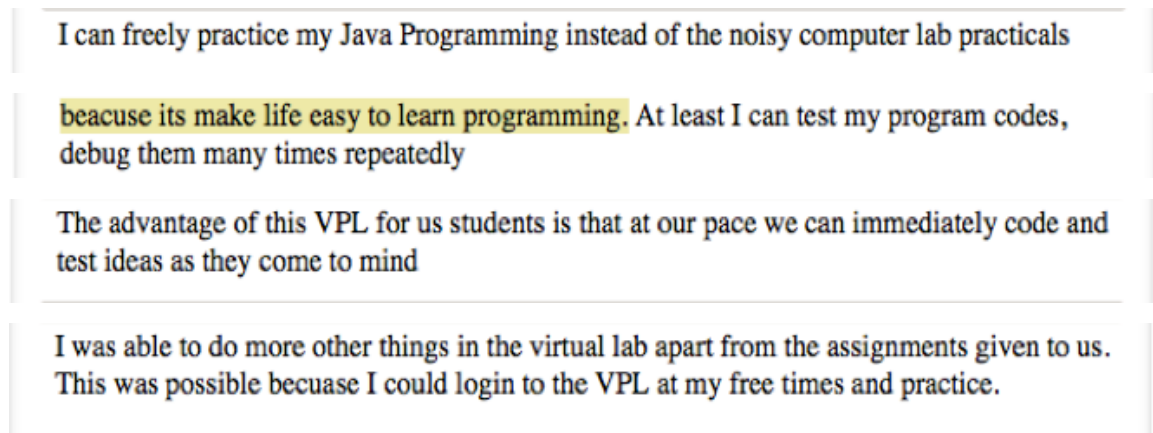


Fig 4.28 Programming Practice Theme Elements (Chats Content)

The first source shows that the learners can practice Java programming freely using the virtual lab without interruption by other students unlike in the traditional computer lab. The second source indicated that the students were able to practice programming using the virtual lab to code, test, and debug their program codes errors. Thus, the virtual lab served as an artifact in the programming activity system to mediate students’ programming practice as illustrated in fig 2.8.

The third source revealed that the virtual lab offered students the opportunity to write and test their Java programming ideas at their own pace. Thus, the virtual lab environment encourages self-practice programming among the students. The fourth source also shows that the virtual lab enables students to practice Java programming at their free

time on their own. Also, this is an indication that the virtual lab (artifact) environment supports and enhances programming practice of the participants (students).

Therefore, this shows that the virtual lab is a cultural tool that the subjects used to performed actions on the activity object (Java programming) in the activity system (Taylor, 2014; Behrend, 2014) as indicated by the respondents' statements: *'I can freely practice my Java programming ...'*; *'... its make life easy to learn programming.'* *'... I can test my program codes, debug them many times repeatedly'*; *'... at our pace we can immediately code and test ideas as they come to mind'*; *'... I could login to the VPL at my free times and practice'* (see fig 4.28 snapshots). Hence, the findings here show that the virtual lab mediates students' practical Java programming practice.

### **Programming Skills Acquisition**

The 'programming skills acquisition' theme contains four (4) different sources as shown in the node snapshots below.

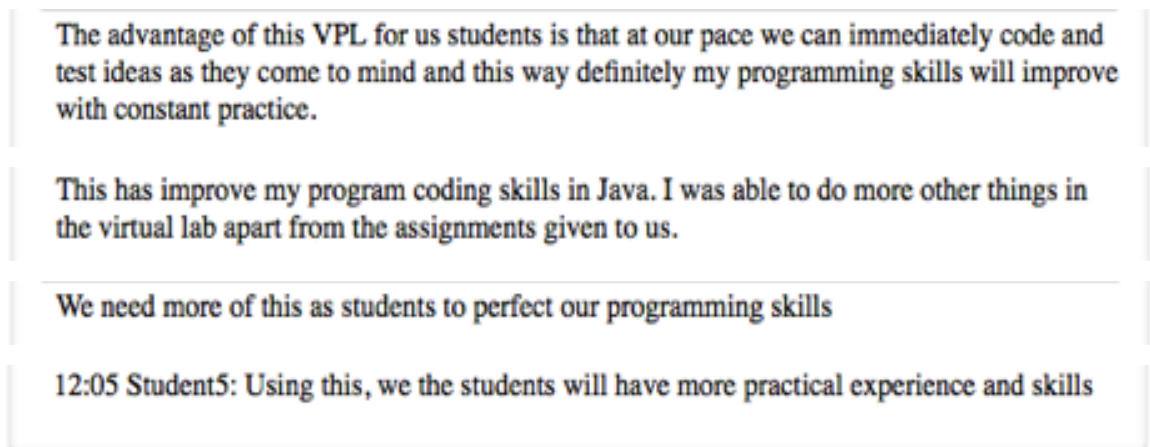


Fig 4.29 Programming Skills Acquisition Theme Elements (Chats Content)

The first source shows that the students viewed the virtual lab as an advantage for them to practice their programming skills. That is, the virtual lab Java programming activity system provides the participating students with opportunity to test and perfect their hands-on programming ability that can mediate their programming skills acquisition as shown in the respondent's statement: '*... definitely my programming skills will improve with constant practice*'. The second source shows how the learner claimed improvement on program coding skills while using the virtual lab environment for their assignments and other programming activities. This can be observed in the respondent's statement: '*This has improve my program coding skills in Java.*' Thus, the virtual lab can mediate students programming skills acquisition if the students appropriately use it.

The third source indicates that the students demand for more engagement with the virtual lab programming activities, and they believed that it would help perfect their programming skills. Similarly, the fourth source indicates that by using the virtual lab, the respondents (students) hoped it would enhance their practical programming experience and skills. Therefore, it can be observed that if students are well engaged with the virtual lab programming activities, it could mediate their practical programming experience and skills acquisition.

In line with Vygotsky's concept of mediated action, the subjects (students and lecturer) in the activity system (i.e. hands-on Java programming) are motivated towards attaining or achieving a purpose or object of the activity while using artifact (virtual lab) (Wilson, 2014; Bozalek et al., 2015, Engeström, 2017a). This motivation towards achieving the activity purpose, can stimulates the students to get

engaged with the hands-on programming activities, which in turn mediates their programming skills acquisition as evident in fig 4.29 by the respondents' statements: *'We need more of this as students to perfect our programming skills'*; *'... we the students will have more practical experience and skills'*. The finding shows that use of virtual lab environment for practical programming activities could stimulates students into constant practice that will in turn mediates their programming skills acquisition.

### **Virtual Lab Accessibility**

The 'virtual lab accessibility' theme contains two (2) sources as shown in the node snapshots below.

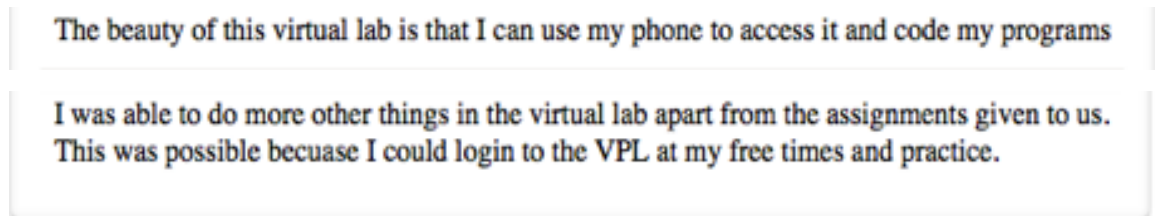


Fig 4.30 Virtual Lab Accessibility Theme Elements (Chats Content)

The first source shows that the virtual lab was accessible using mobile phone to write program codes; this result is similar to what was analysed in 4.3.1.1 above. Thus, the virtual lab environment is accessible even with mobile devices which students have high affinity to their usage as shown the respondent's statement: *'... I can use my phone to access it...'* The second source also indicates that the virtual lab was accessible to students even during non-school hours to practice programming.

The virtual lab as a socio-cultural mediating tool enables the subjects to performed actions on the activity object. These actions include writing program codes, program testing, and program debugging that were performed by the subjects using private devices to access the virtual lab.

Thus, this finding also revealed that the virtual lab mediates subjects' access to a lab environment to carry out hands-on programming activity.

### Virtual Lab Perception

The 'virtual lab perception' theme contains six (6) sources as shown in the node snapshot below.

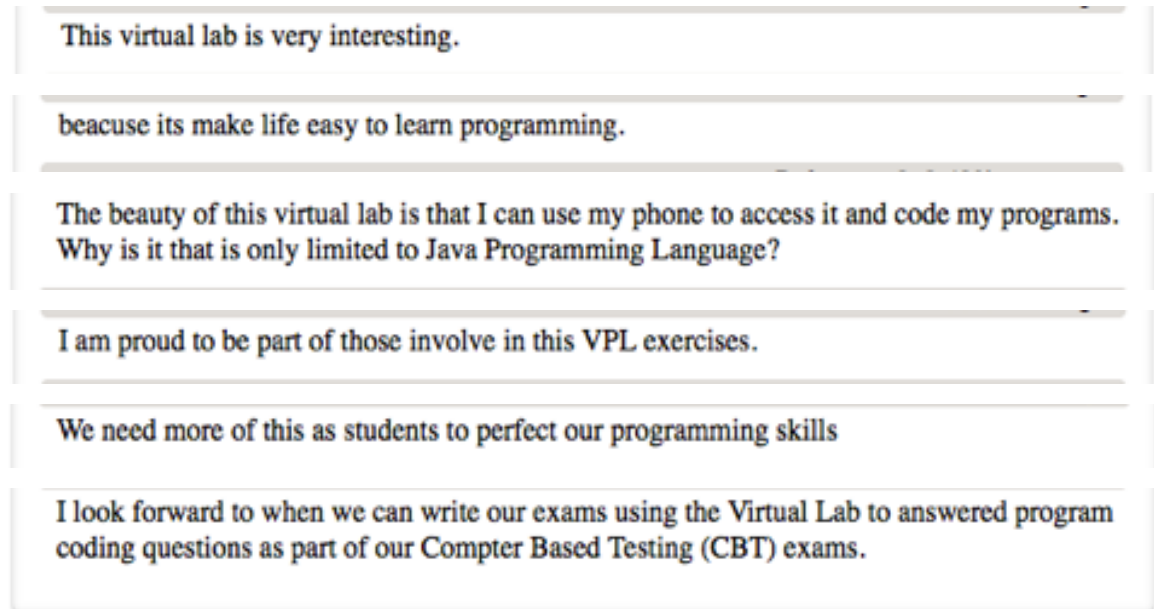


Fig 4.31 VL Perception (Theme Elements - Chats Content)

In the first source, the virtual lab programming experience was perceived as interesting by the participants. The second source shows that students perceived the virtual lab environment as easy to learn programming with. Thus, such perceptions could encourage self-motivation towards programming practice by the students. The third source indicates how students appreciate the affordance of the virtual lab.

The fourth source shows how students perceived and valued their participation in the virtual lab programming activity system, as being proud of. Also, the fifth source shows that the student perceived the virtual lab as a tool that could help enhanced their hands-on

programming skills. The sixth source indicates that the virtual lab is being perceived as opportunity to conduct hands-on programming using Computer-Based Testing (CBT), this is evident by the respondent's statement: *'I look forward to when we can write our exams using the Virtual Lab to answered program coding questions as part of our Computer Based Testing (CBT) exams'* in fig 4.31. Also, as analysed in 4.3.1.1 and 4.3.1.2 above, this finding revealed that the participants have a positive perception towards use of virtual lab for programming practice. These also show that the activity outcome was encouraging and the subjects were motivated. Hence, AT is a powerful theoretical framework to analyse the virtual lab hands-on programming activity system (Clemmensen, Kaptelinin, & Nardi, 2016).

### **Recommendations for Virtual Lab**

This theme's node contains four (4) sources as shown in the node snapshots below.

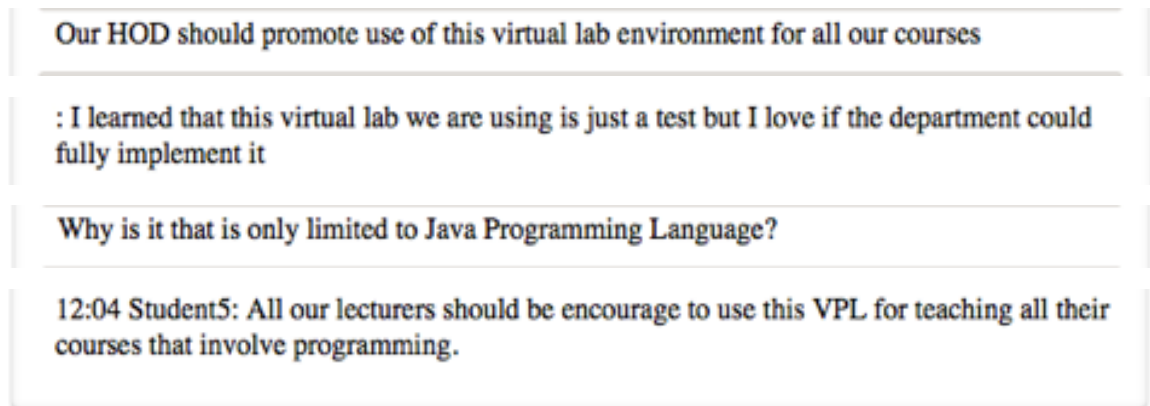


Fig 4.32 Recommendation for Virtual Lab (Theme Elements - Chats Content)

The first source indicates students' recommendation for the adoption of the virtual lab environment to teach all the programming courses in the department. The second source also recommends the implementation

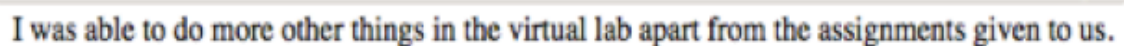
of the virtual lab in the department too. The third source shows that the virtual lab should be used for other programming languages too, that is, not only for Java programming language. The fourth source recommends the virtual lab to all the lecturers in the computer science department to ensure that they teach and conduct practical classes using the virtual lab for all their programming courses.

These are indications that the virtual lab as a cultural tool with meditational function enables the participants to performed their actions driven by the activity object, this assent to Leonardo, & Manning, (2017) description. It's also implied that the virtual lab mediates and mitigates the challenge of having a lab environment for practical sessions and the BYOT policy constraint. The following respondents' statements confirmed this: *'Our HOD should promote use of this virtual lab environment for all our courses'*; *'... I love if the department could fully implement it'*; *'All our lecturers should be encourage to use this VPL for teaching all their courses that involve programming'* as showed on the snapshots in fig 4.32.

These results are similar to what was analysed in 4.3.1.1 and 4.3.1.2 above; therefore, these recommendations could be because of the mediation importance of the virtual lab on the students' programming experience and skills.

### **Students Engagement**

The 'students engagement' theme contains one (1) source as shown in the node snapshot below.



I was able to do more other things in the virtual lab apart from the assignments given to us.

Fig 4.33 Students Engagement (Theme Elements - Chats Content)

This source shows that the virtual lab environment provides a ‘playground’ for the learners to engaged in a self-defined programming practice i.e. doing extra more exercises in the virtual lab on their own. When activity system subjects are motivated to attain the activity object, and the activity product or outcome is encouraging, then the subjects are inspired to continue or participates in future activities. Thus, the resulting outcome of the subjects’ (students) actions encourage them to do more hands-on programming practice in the virtual lab, as indicated by the respondent’s statement: *‘I was able to do more other things in the virtual lab apart from the assignments ...’*. This finding revealed that the students were engaged with the virtual lab programming activities.

#### 4.3.2.2 Forum Content

The virtual lab activities’ forum content was also queried using Nvivo ‘Text Search’ and the search results were visualized using word tree as shown below with more in Appendix J.

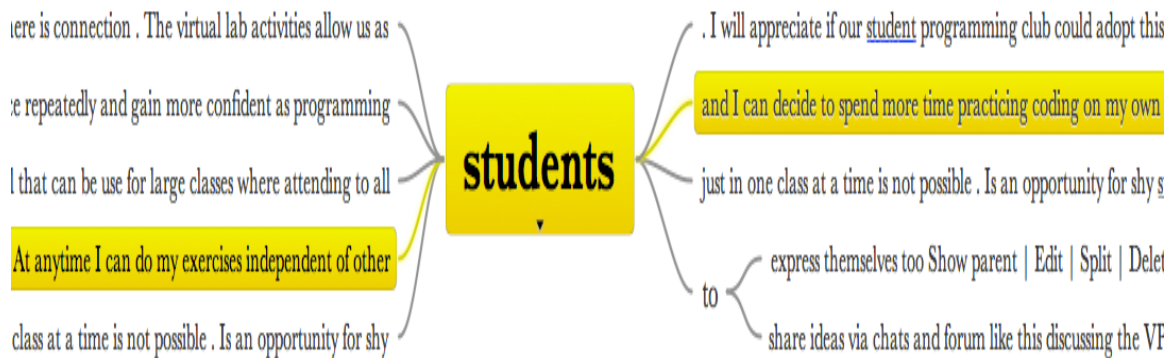


Figure 4.34 Visualised Activity System Forum Content

The statement *‘At anytime I can do my exercises independent of other students and I can decide to spend more time practicing coding on my own’* highlighted in the word tree above shows that the activity system’s mediating tools, rules and division of labour enhanced access to lab

environment at anytime for the subjects to perform actions on the activity object.



Figure 4.35 Visualised Activity System Forum Content

The above highlighted statement, that is, ‘... *it is quite rewarding to practice program coding and debug errors online seamlessly*’ indicates that the activity system rules enhanced division of labour within the community and the artifacts mediate the subject (learners’) program coding.

The forum content was also coded into the following major themes, which enhanced filtering, categorization, and analysis of respondents’ views and experiences with the virtual lab programming activities.

### **Interest in Using VL**

This theme of the forum contains four (4) sources as shown in the node snapshots below.

Working in the virtual lab is the best for any programming practice or learning.
The virtual lab is a friendly practicals environment that enable self-practice at any time and place as long as there is connection.
My experience with the VPL was worthwhile and I like it.
Doing the activities in the Virtual Lab was more interesting than the usual physical lab method that is full of distractions and limited time access to the lab for one to complete his assignments and test them properly before submission

Fig 4.36 Interest in Using VL (Theme Elements - Forum Content)

The first source indicates that the respondent was interested using the virtual lab and considered it the best for programming practice. This could be due to interest on the affordances of the virtual lab. The second source shows that the respondent was interested using the virtual lab environment because it is user-friendly and encourages self-defined programming practices. The third and fourth sources also show that the students like using the virtual lab and considered their experience worthwhile.

Therefore, these comments show that the artifact (virtual lab) help the participants (students) to carry out an activity, and the result of their actions in the activity system appears to be interesting, as shown in their statements: *'Working in the virtual lab is the best for any programming practice or learning'*; *'My experience with the VPL was worthwhile and I like it'*; *'... the virtual lab was more interesting than the usual physical lab ...'* The fourth source also indicates that the students found the virtual lab interesting because there is no distraction in the virtual lab environment and no access time limit.

The activity system rules and regulations guide and direct the subjects' actions, provide procedures for acceptable interactions among the community members (Clemmensen, Kaptelinin, & Nardi, 2016). This implies that the virtual lab activity system rules, the virtual lab inherent cultural features, and the community division of labour promote and support a lab environment that have no access time limit and distractions. This is evident by respondent statement: *'... the virtual lab was more interesting than the usual physical lab method that is full of*

*distractions and limited time access to the lab for one to complete his assignments and test them properly before submission*'. The finding here shows that the respondents have interest in using the virtual lab because there is no access time limit and distractions by peers.

### **Students Engagement**

The 'students engagement' theme of the forum content contains five (5) sources as shown in the node snapshots below.

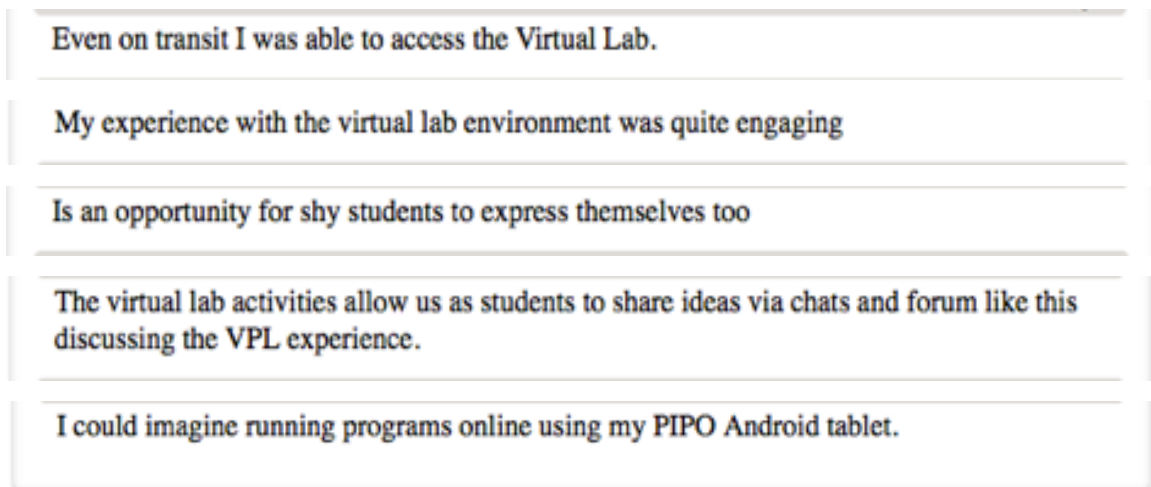


Fig 4.37 Students Engagement (Theme Elements - Forum Content)

The first source indicates that even on transit students were engaged with programming activities in the virtual lab environment. The second source shows that the students' hands-on experience with the virtual lab programming activity system was quite engaging. When activity subjects are encouraged by the artifacts' affordances to attain the activity object, and the activity product or outcome is also encouraging, then the subjects are motivated to participate in future activities or do more. Therefore, this is an indication that the virtual lab activities' outcome was encouraging; hence the subjects (students) were engaged and encouraged to do more hands-on programming practice in the virtual lab

even on transit, as indicated in the statements: *‘Even on transit I was able to access the Virtual Lab’*; *‘My experience with the virtual lab environment was quite engaging’*

The third source shows that the virtual lab environment enables the students to get engaged into sharing ideas among themselves online about their programming activities. The fourth source indicates that the student was able to use an android tablet to perform programming tasks. Again, the virtual lab as a socio-cultural tool mediated the process through its embedded features to enable the subjects used their mobile devices, interacts, and communicates while performing their activities. This is revealed in the statements: *‘Is an opportunity for shy students to express themselves too’*; *‘... allow us as students to share ideas via chats and forum like this discussing on the VPL experience’*

Thus, this result shows that using virtual lab environment for practical classes could engaged the learners into learning more on their own at even odd times.

### **Programming Practice**

The ‘programming practice’ theme contains three (3) references as shown in the node snapshot below.

My experience with the virtual lab was encouraging for me because I was able to practice repeatedly and gain more confident as programming students.

it is quite rewarding to practice program coding and debug errors online seamlessly.

At anytime I can do my exercises independent of other students and I can decide to spend more time practicing coding on my own.

Fig 4.38 Programming Practice (Theme Elements - Forum Content)

The first source indicates that the virtual lab is encouraging and students were able to use it to practice programming repetitively as maintained by Heradio, et al, (2016), which could developed their confidence in programming. Therefore, it can be observed the virtual lab activity system subjects performed actions on the activity that is driven by the object; and directed by the rules to achieve the outcome. Also, this aligned with the activity system in fig 2.8. This achievement of the outcome promotes and encourages the subjects to further practice or perform the activities as indicated in the statements: *'... I was able to practice repeatedly ...'*; *'... and I can decide to spend more time practicing coding on my own'*.

The second source shows that the virtual lab enables students to practice programming online seamlessly. The third source indicates that students can practice and complete their programming exercises independently using the virtual lab environment. Also, using the theoretical framework lens, this shows that the activity system artifact (virtual lab), rules and regulations, and the division of labour between the community members, all enhanced the subjects to participate and performed their actions on the activity. These mediate the hands-on programming practice among the students as evident in the statements: *'... practice program coding and debug errors online seamlessly'*; *'At anytime I can do my exercises ... and I can decide to spend more time practicing coding on my own'*.

Therefore, this finding as in 4.3.1.1 and 4.3.2.1 shows that using the virtual lab for hands-on programming activities could encourage

programming practice and developed students' programming skills as potential programmers.

### **VL Compare to Traditional Lab**

The 'VL compare to traditional lab' theme contains two (2) sources as shown in the node snapshot below.

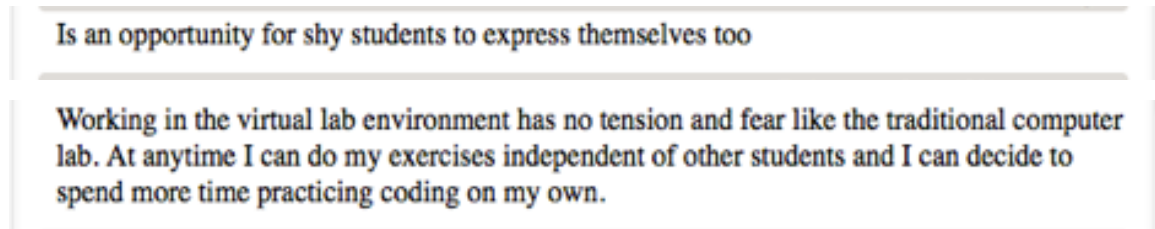


Fig 4.39 VL Compare to Traditional Lab (Theme Elements - Forum Content)

The first source shows that the virtual lab environment could encourage shy students to express themselves, communicates with others and their lecturer online unlike in physical lab environment. The second source shows that students working in the virtual lab environment have no tension unlike in the physical lab where there is fear of making mistake in the presence of the lecturer or peers and tension of trying to finish and submit before the 'lab hour' elapse. Hence, the virtual lab provides opportunity for self-pace and independent programming practice and learning unlike in the physical lab environment.

It implies that the artifact (virtual lab) as a cultural tool help the subjects (students) to carry out hands-on programming activities in the virtual lab environment at self-pace and without tension. This is evident in the respondents' statements: *'Is an opportunity for shy students to express themselves ...'*; *'... virtual lab environment has no tension and fear like the traditional computer lab ...'*; *'... I can do my exercises independent of other students ...'*. Therefore, as analysed in 4.3.1.1 and

4.3.2.1, this result demonstrates that the virtual lab mediates the challenge of lab access (limited number of computers in physical lab) for practical programming classes and the policy constraint against BYOT. As a socio-cultural tool, the virtual lab also enhanced interactions and communications among the members of the activity system community (Alkhaldi, Pranata, & Athauda, 2016).

### **Recommendation for Virtual Lab**

This theme contains four (4) sources as shown in the node snapshots below.

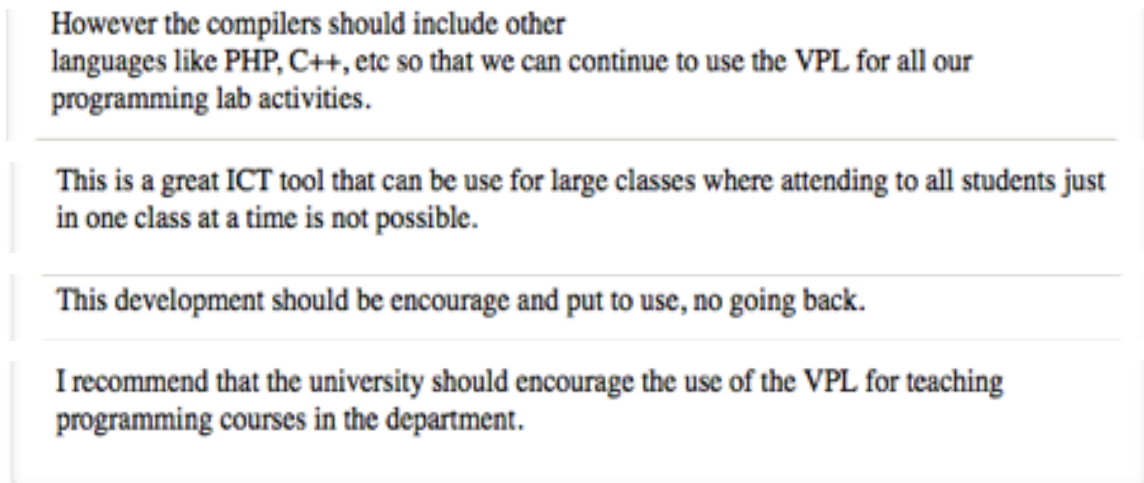


Fig 4.40 Recommendation for Virtual Lab (Theme Elements - Forum Content)

It can be observed from the first source that the students wish to have other compilers like C++ on the virtual lab so that they could use the virtual lab for all their programming activities. However, this could be a recommendation for implementation of the virtual lab to cover other programming languages as evident in the statement: '*... the compilers should include other languages like PHP, C++, etc so that we can continue to use the VPL for all our programming lab activities*'. In AT

voice, and as found in 4.3.1.1, 4.3.1.2 and 4.3.2.1 above, this shows that the artifact i.e. virtual lab is recommended for practical programming to enable the subjects (students & lecturer) conduct practical programming classes and activities.

The second source shows that the virtual lab could be use as ICT tool to conduct practical programming classes for large students' number; where it could be difficult for a lecturer to provides feedback to all students during practical classes in traditional lab setting that usually has limited practical time duration. Thus, this can be a recommendation of the virtual lab for large class size practical sessions.

The third source indicates that the virtual lab should be encouraged and implemented. The fourth source shows that the virtual lab is recommended for teaching programming courses in the department.

All these findings revealed that the virtual lab (artifact) as a social and cultural-historic resource, it could mediate hands-on programming learning activities by enabling the subjects to interact and communicates within the activity system community. This mediation includes enabling lab environment, ability to provide immediate feedbacks to students on their practical activities, and mitigating the BYOT policy constraints as evident in the respondents' statements: '*... can be use for large classes where attending to all students just in one class at a time is not possible*'; '*This development should be encourage and put to use, no going back*'; '*I recommend that the university should encourage the use of the VPL for teaching programming courses in the department*' on fig 4.40 snapshots.

## **VL Perception**

The ‘VL perception’ theme contains two (2) sources as shown in the node snapshots below.

My experience with the virtual lab environment was quite engaging. It is the best thing that can happen to any computer science student.

The virtual programming lab is a wonderful experience for me; I could imagine running programs online using my PIPO Android tablet.

Fig 4.41 VL Perception (Theme Elements - Forum Content)

It can observe from the first source that the virtual lab is perceived as engaging and good for computer science students. The second source indicates that the virtual lab experience is perceived as wonderful.

These imply that the hands-on programming activity outcome was encouraging to the subjects; thus, they perceived it as engaging and worth it. Therefore, as found in 4.3.1.1 and 4.3.2.1, this result shows that the virtual lab is perceived as a cultural tool essential for practicing programming and that it could mediate students’ hands-on programming experience and skills, as supported by these respondents’ statements: ‘... *the virtual lab was quite engaging*’; ‘*It is the best thing that can happen to any computer science student*’; ‘*The virtual programming lab is a wonderful experience for me ...*’

### **Programming Skills**

The ‘programming skills’ theme contains one (1) source as shown in the node snapshots below.

I will appreciate if our student programming club could adopt this VPL as a practice environment that hopefully will train us to be good programmers.

Fig 4.42 Programming Skills (Theme Elements - Forum Content)

The source indicates that using virtual lab environment for programming practice can mediate learners programming experience and skills. This revealed that the virtual lab as a social and cultural artifact, it could mediate students programming experience and skills by providing a lab environment for hands-on programming practice. This is similar to what was analysed in 4.3.1.1 and 4.3.2.1 and evident in the respondent's statement: *'I will appreciate if our student programming club could adopt this VPL as a practice environment that hopefully will train us to be good programmers'* as inscribed on fig 4.42 snapshot above.

The activity system on fig 2.8 (which is based on the analytical framework on fig 2.7) is reviewed based on these results or findings as shown below.

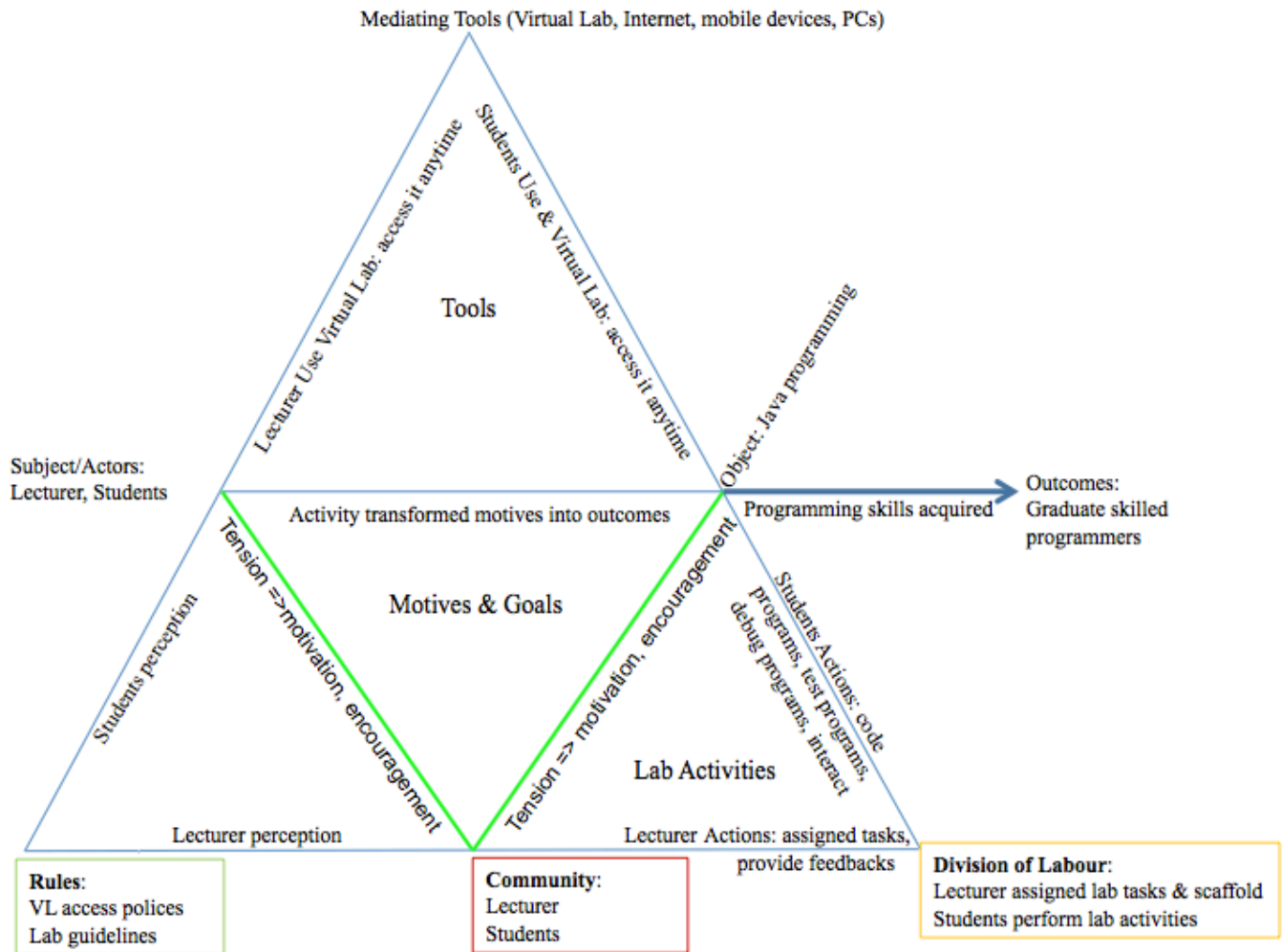


Fig 4.43: Virtual Lab Java Programming Activity System

It can be observed that this activity system as compare to the one in fig 2.8, the contradictions or tensions have changed to motivation and encouragement (as depicted with green lines in fig 4.43) after the subjects (lecturer and students) have performed actions on the activity object. Thus, the respondents' statements: '*... virtual lab is the way forward for our department in teaching all programming courses because we cannot be able to conduct all programming practical in our small physical computer lab that have few systems*' (see snapshots in fig 4.24) and '*... virtual lab environment has no tension and fear like*

*the traditional computer lab ...*’; *‘... I can do my exercises independent of other students ...’* (see fig 4.39 snapshot) are as result of the motivation and encouragement. The motivation and encouragement to use the artifact (virtual lab) can promote hands-on programming practice by the students, which can also mediate their programming skills acquisition.

The actions performed on the activity object include assigning programming tasks by the lecturer, scaffolding of students’ performance, providing them with feedbacks; while the students performed the tasks by coding programs, testing programs, and debugging programs. These are evident in the respondents’ statements: *‘... I was able to set Java programming assignments for students and check their submissions using my iPad.’* *‘I was able to view and comments on students’ lab activities online even at home’* (see fig 4.21 snapshots), *‘... practice program coding and debug errors online seamlessly’* (see fig 4.38 snapshots), *‘I can test my program codes, debug them many times repeatedly’*; *‘... at our pace we can immediately code and test ideas as they come to mind’*; (see fig 4.28 snapshots).

From fig 4.43 above the outcomes of the AT system is “artifacts’ mediated programming skills and experience”, that is, the virtual lab activity system can mediate programming skills acquisition if the community members appropriately used it as indicated by the respondents’ statements: *‘... definitely my programming skills will improve with constant practice’*, *‘this has improve my program coding skills in Java’* (see fig 4.29 snapshots), *‘I gain more skills on programming using the virtual lab’*, *‘Using the virtual lab will improve my programming skills very well’*, *‘using the virtual lab enable me to*

*practice a lot of things on my own...’, ‘...and this make us better future programmers’* (see fig 4.9). Thus, the findings illustrates that use of the virtual lab enhances students’ Java programming skills acquisition, and:

1. provide alternative computer lab engagement
2. provide flexible access to the lab for students to carry out programming tasks, and the lecturer to scaffold students' program coding ability.
3. enable students' hands-on programming assessment where formative feedback would help enhance their skills

Therefore, these aligned with the purpose and the main objective of this research work, that is, to find out whether use of virtual lab would enhance students’ Java programming skills acquisition in the Computer Science department at UniJos.

#### **4.4 Results Discussion**

The results of data analysed above from the two different sources (i.e. interview, and activity system contents) are discussed below in sequence to point out findings and their linkage with the research questions.

##### **4.4.1 Interview Results**

The research interview instrument engaged both the students and the lecturer, where a lot of information was collected through audio recording. The recorded interviews were transcribed and analysed, thus, the results and findings are discussed as follow:

###### **4.4.1.1 Results from Students’ Interview**

During the interview, the students’ views show that their experimentation with the virtual lab was worthwhile. The virtual lab

encourages independent and self-paced hands-on programming practice, which could enhance programming skills acquisition. This agrees to (Savić, et al., 2016; Kori, et al., 2016; Farooq, & Khlad, 2013; and Bowlick, Goldberg, & Bednarz, 2017) views on hands-on practice that could mediate students' programming skills acquisition and also groomed them as potential programmers.

The students' experience with the virtual lab environment exposes them to a new way of conducting hands-on programming practice (see section 4.3.1.1). Thus, the activity system exposes the subjects (learners) to a new pedagogical option on how practical programming classes could be conducted. Therefore, this interview result answered the third researchable subsidiary question i.e. *'What are the teaching and learning practices evident in the virtual lab?'* as indicated on table 3.1.

The results of the students' interview show that using the virtual lab enable learners to spend more time practicing program coding on their own including leisure time. This also promotes and enhances students' practical programming experience and skills that could equip them as skilled graduates to be and future programmers that will require little or no training to work in a production environment when employed as maintained by Bringula, Balcoba, & Basa, (2016); Baruah, Ward, & Brereton, (2017); and Acheampong, (2013). Therefore, in line with table 3.1 above, this result addresses the second researchable subsidiary question (*'How does the virtual lab programming mediate students' programming skills acquisition?'*), i.e. the virtual lab programming activity system mediates the students' programming skills through constant programming practice using the virtual lab as a mediating tool.

The students' interview as earlier analysed revealed that the subject (lecturer) was able to provide each of them with instant feedbacks on their lab activities. This is evident in figure 4.11 i.e. the respondent's statement: '*... the instant feedback from the lecturer help me to correct my mistakes*', hence making feedback process easy as maintained by Rodríguez-del-Pino, Rubio-Royo & Hernández-Figueroa (2012:80); and Robinson, & Carroll, (2017). This implies that the activity system rules enable the subjects (lecturer and students) to interact and communicate as members of the community, each participating based on the division of labour using artifacts. Thus, this could also stimulate and encouraged the subject (students) to practice more on their own (self-engagement) through self-motivation and determination. The self-engagement with hands-on programming practice can promote authentic learning of programming concepts they learned in class (Potkonjak, et al, 2016; Cheng, Chen, Liu, & Huang, 2016; Pelet, Khan, Papadopoulou, & Bernardin, 2015).

The interview result also indicates that the virtual lab is usable and accessible anytime and place with private computers, mobile devices like tablets, and smart phones to practice program coding even on transit. This shows that the artifact (virtual lab) mediates the subjects' access to a lab environment to carry out hands-on programming activities. Thus, this flexibility of access to the artifact (virtual lab) offers the subjects (students) the opportunity to spend more time on hands-on programming practice compare to physical lab.

Therefore, this addressed the second research objective, i.e. '*to provide flexible access to lab for students to carry out programming tasks, and for the lecturer to scaffold students' program coding ability*'.

This also agrees with Johns-Boast (2014:199-201) position on hands-on activities and scaffolding as requirements for impacting technical and practical competency on learners of professional courses.

The interview results also revealed some recommendations for the adoption, implementation and domestication of the virtual lab programming activity system as follows:

- The virtual lab is recommended for implementation in the computer science department for teaching all programming courses because of the virtual lab's accessibility affordance in terms of time and place.
- The virtual lab is recommended for adoption by all the lecturers in the computer science department
- The virtual lab is recommended to the entire university because of its cost effectiveness and affordance compare to physical lab

The following statements by the respondents showed on the snapshots of the transcribed interview in fig 4.14 are evidences: *'I will like the department to make sure all our lecturers use the virtual programming lab to teach all our courses'*, *'I will really urge the university and the department to take this very seriously to go beyond just one programming language'*, *'... I recommend the adoption of this important concept'*

It could be said that, this is an indication that the virtual lab activity system intervention for Java programming language practical classes was worthwhile and a welcome development that could be adopted.

The interview results recognized the virtual lab as a cost-saving artifact for conducting practical programming activities in the context of computer science department of UniJos; where there are limited

numbers of computers in the physical lab for all students to use concurrently. This finding supports (Chen, Song, and Zhang 2010:3844; Oliveira, Marranghello, Silva, & Pereira, 2016; and Hovardas, Xenofontos, & Zacharia, 2017) assertions that virtual lab can be use for practical activities that would normally require equipment that is too expensive or unavailable.

The results show that the subjects (students) preferred the virtual lab to the traditional lab for the following reasons:

- The virtual lab could allow or enable introverts students to expressed themselves virtually and work without tension or nervousness
- The virtual lab can be access anytime anywhere unlike the physical lab that it must be inside a fix place
- The virtual lab is cost-effective unlike physical lab that is capital intensive
- Students gets instance feedbacks and gain their lecturer's attention online
- The virtual lab can be access using mobile devices

The statements '*... in virtual lab environment I express myself better*'; '*I definitely preferred the VPL because of easy accessibility ...*'; '*While with VPL either with a phone or any capable device I can have access to a full programming compiler ...*', and '*... but virtual lab can be access by many students at the same time.*' as shown on the snapshots in figure 4.17 are evidences that the activity system artifacts (virtual lab, mobile devices) have the mediation function to mediate access to lab environment and the challenge of limited number of computers in a physical computer lab.

Therefore, these reasons suggested that the artifact (virtual lab) could be an alternative to traditional physical lab for hands-on programming activity system good for independent, self-pace, and student-centre hands-on programming practice. This supported Tatli, & Ayas, (2013) position on using virtual lab as alternative lab to physical lab.

#### **4.4.1.2 Results from Lecturer's Interview**

During the interview interaction, the lecturer acknowledges the virtual lab as useful, easy to access and used; and as a valuable tool that could enhance management of students' hands-on program coding online. The respondent's statements affirm this: *'... I was able to set Java programming assignments for students and check their submissions using my iPad', 'I was able to view and comments on students' lab activities online even at home'* in figure 4.21 snapshots.

This could be achieved through provision of feedbacks to students and scaffolding on their individual practical programming activities base on their ZPD in programming (Engeström 2014:134-135; Roth, 2014; and Ng'ambi & Brown, 2014: 46-47), as evident by the respondent's statement: *'I was able to attend to each student in the VPL environment'* in figure 4.21. The feedbacks given to the subjects (students) could help mediate their programming skills as maintained by Robinson, & Carroll, (2017); Chen, DeMara, Salehi, & Hartshorne, (2017). This also addressed the third research objective, that is, *'To enable students' hands-on programming assessment where formative feedback would help enhance their skills'*.

The ability to manage a class is very important in any form of teaching either formal/informal or face-to-face/online (Dawson, & Al

Saeed, 2012). Thus, the affordances of the artifact (virtual lab) that enable the subject (lecturer) to manage and scaffolds the learners in the activity system is a vital attribute or characteristic that could encouraged and hearten the adoption and implementation of the virtual lab for practical programming activity systems.

The results of the interview also shows that at the beginning the lecturer was not sure about the ability or capability of the artifact (virtual lab) for conducting online hands-on programming activities until he experienced it. This was confirmed by the lecturer's statement: *'I must confess that the virtual lab experience has shaped my pedagogical thoughts and approach to teaching programming courses'* in figure 4.23 snapshots. Therefore the subject's motives for participating in the activity were contradictions or tensions in the activity system (Engeström, 2017b; Bravo Olavarria, 2013).

However, the subject's actions transformed the object in reaction to these contradictions in the activity system. This imply that the lecturer pedagogical position towards use of the virtual lab for teaching programming courses have changed after experiencing the virtual lab. That is, his pedagogical view was reshaped by the affordances of the artifact in practical programming activity system. Thus, AT can be employed as a methodological tool to investigate pedagogical change within a classroom (Hardman (2005:1; Engestrom, 2014).

This realisation and views of the lecturer about use of the virtual lab to conduct hands-on programming activities has countered the anxiety or nervousness exhibited by educators of professional courses like computer science in embracing eLearning for distance learning as

maintained by Dalgarno, Bishop, & Bedgood Jr (2012:90) and Wang (2012:1745).

The educator's experience with the virtual lab environment for practical programming activities have induced him to recommends the adoption and implementation of the virtual lab as follows:

- The lecturer recommends the implementation and full usage of the virtual lab as alternative way forward for conducting all hands-on programming activities in the computer science department
- He recommended the virtual lab for all science departments to enhance their students' practical activities.

The following statements of the respondent attest to these as shown on snapshots in figure 4.24: '*... virtual lab is the way forward for our department in teaching all programming courses because we cannot be able to conduct all programming practical in our small physical computer lab that have few systems*'; '*... virtual lab could also be use by other science department for conducting their practical*'

#### **4.4.2 Activity System Contents Results**

There were two forms of contents being analysed about the virtual lab programming activity system, that is, the chats and forum contents. The contents were captured, coded, analysed and the results are discussed below.

##### **4.4.2.1 Chats Content Results**

The results of the chats content indicates that the students perceived the virtual lab as an interesting programming lab environment that they desired to used it for all their programming courses in the department.

They also wish to write programming exams using the virtual lab. The respondents' statements: *'This virtual lab is very interesting'*; *'I look forward to when we can write exams using the Virtual Lab to answered program coding questions as part of our Computer Based Testing (CBT) exams'* in fig 4.27 and fig 4.31 respectively are evidences.

With the virtual lab activity system, students can use their waiting or transit time to practice programming at their own pace. That is, they can code programs as ideas flows in their minds, test and debug the programs many times as maintained by Oliveira, Marranghello, Silva, & Pereira, (2016); Chen, Song, and Zhang (2010:3844), Tatli, & Ayas, (2013); Lewis, (2014). This shows that the artifact (virtual lab) enable the subjects (students) to perform actions (i.e. program coding, testing and debugging) on the activity object and repeats it many times. This repeated programming practice can mediate their practical programming skills as stated by the respondents in fig 4.29 snapshots, i.e. *'... definitely my programming skills will improve with constant practice'*, and *'This has improve my program coding skills in Java'*.

Therefore, this result also answered the second research question i.e. *'how does the virtual lab programming mediate the students' programming skills acquisition?'* as stated in table 3.1. Thus, the virtual lab is an artifact that can be deployed and used to mediate students' programming skills as explained by Engestrom (2017b) and supported by Aguayo, (2016).

The result as earlier analysed above in section 4.3.2.1 shows that the virtual lab is accessible to authorized persons anywhere anytime using even mobile devices that contemporary students have lofty affinity to their usage (Šorgo, et al, 2017; Fernández, et al, 2017). The respondent's

statement in fig 4.30 snapshot affirmed to this, i.e. ‘... *I can use my phone to access it...*’ Therefore the accessibility attribute of the artifact (virtual lab) as socio-cultural mediating tool influenced and encouraged the subjects (students) to be engaged with hands-on programming activities.

The chats content results identified some recommendations made by the participants as follows:

- The participants recommend full implementation of the virtual lab for all programming courses in the department of computer science. This same recommendation was also made in the interview (see section 4.4.1.1).
- The participating students recommended the use of the virtual lab to enable them write computer-based hands-on lab programming examinations. This recommendation call for a new approach to how Computer-Based Testing (CBT) exams are conducted in the UniJos and in the department of computer science in particular. This could also help the educators to perform a formative measurement and evaluation of the students’ hands-on skills and experience.
- Similar to one of the recommendations made during the interview (see section 4.4.1.1), the respondents recommend the use of virtual lab to all the lecturers in the department. That is, to enable the lecturers to teach and conduct practical classes using the virtual lab for all programming courses.

These recommendations are not different from those ones previously stated, thus, they emphases the necessity and worthiness of the virtual lab as a mediating tool for conducting practical programming activities.

#### 4.4.2.2 Forum Content Results

The results of the forum content are not far different from that of the chats content. The results show that the subjects (students) are enthralled with the virtual lab programming activity system because the artifact (virtual lab) is user-friendly, quite engaging, and accessible even with mobile devices. All these enable the subjects (students) to performed actions (i.e. practice program coding, test their codes, debug and fix bug issues) on the activity object at own pace and independent of others.

Hence, this supports CHAT theorists' (Bozalek et al., 2015; Bravo Olavarria, 2013; Leonardo, & Manning, 2017) description of artifacts as cultural tools with mediation function, which help participants of an activity system to carry out an activity. Therefore, use of ICTs have opened a new sphere for teaching and learning with web-delivered interactive environment and offered great improvement in communication within the academic community as asserted by Berenguel, et al, (2016). This shows that using the virtual lab for practical programming classes could stimulates students' interest in learning and practicing program coding; and the interest can also encourage constant practice that could mediate programming skills acquisition. Therefore, from AT methodological framework and Hardman (2005:1) findings, the virtual lab experience could lead to a pedagogical paradigm shift in conducting practical programming activities in the context of UniJos.

The results also indicate a positive perception of the virtual lab by both students and the lecturer. This perception can widen the practical programming ZPD of the learners to explored more in their practical programming learning processes (Engestrom, 2014). Also the lecturer

could clinch and support full (including practical sessions) implementation of eLearning for all their programming courses in the department.

Viewing these results with AT lens, it can be seen that the results of both the forum and chats contents acknowledges the artifact (virtual lab) as valuable programming lab environment that enables the subject (educator) to interact, guide and assist all the students with their hands-on programming challenges. The major advantage of the virtual lab is that even at home, on transit, the educator can access the learners' lab activities and scaffold or provides them with feedbacks (see respondent's statement in section 4.3.1.2 on fig 4.21 snapshots: *'I was able to attend to each student in the VPL environment'*) either synchronously or asynchronously as stated by (Farooq, & Khlad, 2013). The following statements by respondents confirm these: *'I was able to view and comments on students' lab activities online even at home'* (section 4.3.1.2 on fig 4.21 snapshots), *'Even on transit I was able to access the Virtual Lab'* (section 4.3.2.2 on fig 4.37 snapshots), and *'I was able to attend to each student in the VPL environment'* (section 4.3.1.2 on fig 4.21 snapshots).

The activity system rules enable the subjects (students) to interact among themselves using chats, forum, and/or other media online. Therefore, the virtual lab as a socio-cultural tool can also engage shy learners in the learning process unlike in physical lab that shy students are being mute. Hence, depriving them from sharing brilliant ideas they might have. Such hands-on programming engagement can build their confidence as programmers and mediates their programming skills acquisition; this supports Clemmensen, Kaptelinin, & Nardi, (2016)

findings on sustaining the continuity of interaction in web-based practical for engineering education. Thus, activity theory is a powerful theoretical lens to viewed and explained how interaction with ICT tools in learning activities can mediate hands-on skills acquisition.

The forum content results also include recommendations for the adoption of the virtual lab as follows:

- The virtual lab is recommended for all programming courses in the computer science department and
- The virtual lab is recommended for teaching large class size programming classes

The following statements of the respondents in section 4.3.2.2 on fig 4.40 snapshots affirmed these: *'... can be use for large classes where attending to all students just in one class at a time is not possible'*; *'This development should be encourage and put to use, no going back'*; *'I recommend that the university should encourage the use of the VPL for teaching programming courses in the department'*.

It can be observed that the respondents presented similar views and recommendations independent of instruments. This implied that the results as discussed represented their views, experiences, and opinions about the virtual lab programming activity system.

## **4.5 Chapter Summary**

The research data collected using interviews were recorded in audio format only having obtained respondents' permission and consent. These audio data were imported into and transcribed using Nvivo; and snapshots of the transcriptions were presented in this chapter. Similarly, the activity system contents generated in form of forum and chats about

the virtual lab Java programming activities were captured using Nvivo Ncapture feature. The captured activity system contents' snapshots were also presented.

The interview transcriptions were explored using Nvivo text search query. The resulting queries' output were visualised using word trees (see sections 4.3.1.1 and 4.3.1.2). Also, the activity system contents (forum and chats) were explored and visualised in the same way using word trees (see sections 4.3.2.1 and 4.3.2.2). The transcribed interviews data and the activity system contents (forum and chats) data were coded thematically where patterns emerges naturally and grouped into themes. Each theme contained related research data in a node and the themes were analysed separately using AT as the theoretical framework (see sections 4.3.1.1, 4.3.1.2, 4.3.2.1, and 4.3.2.2). Also the research results were discussed respectively in sections 4.4.1.1, 4.4.1.2, 4.4.2.1, and 4.4.2.2.

Viewing the discussed results and recommendations made by the research respondents using activity theory's lens, it can be deduced that the artifact (virtual lab) can enhance and mediates subjects (students) programming experience and skills. Also, their recommendations are informed by the mediation's importance of the virtual lab on their programming skills.

## **5 CHAPTER 5: SUMMARY AND RECOMMENDATIONS**

### **5.1 Introduction to the Chapter**

Base on the results presented, visualized, analysed and discussed in the previous chapter; a review of the research questions and conclusion are presented in this chapter. Suggestions for practice or adaptation and implementation of the virtual lab in UniJos or any institution with similar background are unpacked in this chapter. Recommendations for further research are also presented.

### **5.2 Review of Research Questions**

The primary aim of this study is to investigate how use of virtual lab as an emerging technology (in the context of UniJos) could mediate students' programming skills acquisition. The main question this research sought to address is: *“How does the use of a virtual lab mediate Java programming skills acquisition amongst computer science students?”* Using CHAT helped me view and explained students' engagement with the virtual lab programming activities mediated by many contextual features like tools, the community, rules, and division of labour (Engestrom, 2017; Engestrom, 2014). The research work was carried out to understand how these contextual features (e.g. tools, rules, community, and division of labour) enhance the programming skills acquisition of the students. The purpose was to understand how institutions like UniJos, in Nigeria could explore the use of the virtual lab for teaching and learning practical programming language courses.

The following outline the research findings base on the subsidiary research questions.

### **5.2.1 What is the objective of the virtual lab programming?**

The opportunity for students to engage in practical programming activities is an essential component of degree programmes in the Computer Science as maintained by Bowlick, Goldberg, & Bednarz, (2017). In a situation where there are limited number of computers in a computer lab and resistance to concept of BYOT; the mobility of access to virtual lab environment provides students with the opportunity to get engaged with hands-on programming activities. This aligned with Lewis, (2014) assertion on accessibility affordance of the virtual lab.

As maintained by Oliveira, Marranghello, Silva, & Pereira, (2016), this can encourage self-pace and tension-free practical programming learning process using private computers and mobile devices from home, in the hostels, and at hotspots. Therefore as stated in section 4.3.1.1, the artifact (virtual lab) mediates the subjects' access to lab environment to carry out hands-on programming activities. This is supported by (Tatli, & Ayas, 2013; Hovardas, Xenofontos, & Zacharia, (2017) positions that virtual lab provides the required environment for students to demonstrates and converts their theoretical knowledge into practical knowledge and experience through lab practice.

The virtual lab enables the lecturer to scaffold the students online either synchronously or asynchronously. The virtual lab programming activity system promotes student-centred and self-pace hands-on Java programming practice, this concurred with Potkonjak, et al (2016). Such hands-on programming engagement could build students confidence as potential programmers and mediates their programming skills as analysed in sections 4.3.2.1 and 4.3.2.2.

Analysing the activity system using AT lens, it was found that the artifact (virtual lab) is a socio-cultural tool that enable the subjects (both students and the educator) to interact as members of the community through their actions on the activity object (see section 4.3.1.1). This concurred with (Engeström, 2017a; Clemmensen, Kaptelinin, & Nardi, (2016) positions that activity theory is a powerful theoretical lens to view and explain interactions within an activity system. Therefore, it can be said that the main objective of the virtual lab programming activity system is to provide students with programming lab environment for their practical programming sessions and activities that supplement or serve as alternative to physical lab.

### **5.2.2 How does the virtual lab programming mediate students' programming skills acquisition?**

Practical programming activities re-enforces knowledge and understanding of contents and concepts taught in theoretical sessions. It provides the opportunity for learners to developed competence in practical skills appropriate to their discipline, as maintained by (Furberg, 2016; Hidayat, & Utomo, 2015).

It was found that the students viewed the vital lab as an interesting programming lab environment that allowed them to spend more time practicing program coding, testing, and debugging (see sections 4.3.2.1 and 4.3.2.2). The virtual lab environment provides the subjects (students) with an opportunity to repeat their lab exercises many times before submissions (see sections 4.4.2.1 fig 4.38 snapshots and 4.3.2.2 fig 4.38 snapshots). This concurred to Alkhaldi, Pranata, & Athauda, (2016); Chen, Song, and Zhang (2010:3844); Tatli, & Ayas, (2013);

Lewis, (2014) findings and assertion that virtual lab provide students with opportunity to repeat tasks many times (see section 2.3). This can re-enforce understanding and also mediates hands-on programming experience and skills.

Therefore, it can be said that the interaction of the subjects (both students and the lecturer) with the artifact (virtual lab) in Java practical programming learning activity system helps mediate students' hands-on programming skills. This could be possible through frequent guided hands-on programming practice as analysed in sections 4.3.1.1, 4.3.2.1 and 4.3.2.2. From the aforementioned, it can be observed that the virtual lab is an artifact that can be deployed and used to mediate students' programming skills acquisition as explained by Engestrom (2017b) and supported by Aguayo, (2016) and Hardman (2005). Thus, the virtual lab programming mediate students' programming skills acquisition through guided constant hands-on practice with scaffolding.

### **5.2.3 What are the teaching and learning practice evident in the virtual lab?**

The ability to access the virtual lab using mobile devices opens new direction for the students on how to use their smart devices for hands-on programming learning purposes (see sections 4.3.1.1, 4.3.2.2, and 4.4.1.1). This assent with Cordeiro, Fonseca, & Alves, (2015) statement that the virtual lab environment embedded pedagogical strategies, technologies and learner's needs to enhance practical teaching and learning experiences. Conducting practical programming activities using the virtual lab for contemporary learners who have high affinity towards using smart devices is like teaching them in their socio-cultural context

(Šorgo, et al, 2017; Fernández, et al, 2017). It gives them the opportunity to construct their learning, hence, the virtual lab environment support and encourages student-centred and authentic learning as ascribed by (Cheng, Chen, Liu, & Huang, 2016; Oliveira, Marranghello, Silva, & Pereira, 2016; Potkonjak, et al., 2016).

Using activity theory as a methodological tool, it was found that the students' experience with the virtual lab environment exposes them to new way of performing hands-on programming practice (see sections 4.3.1.1 and 4.3.2.2), as maintained by Galan, et al, (2017); Encalada, & Sequera, (2017). Also, the lecturer's pedagogical approach or position towards the use of the virtual lab for teaching and learning practical programming courses changed after his experience with the virtual lab programming activities as analysed in section 4.3.2.1. This revealed that the pedagogical techniques for teaching and learning with the virtual lab are slightly different, that is, it employed the use of online collaboration, problem-based learning, inquiry-based learning, experiential learning, and constructivist learning approach assent by Kaunang, et al, (2016).

The ability to provide students with instant feedbacks on their practical programming activities within the virtual lab programming activity system was a vital motivational motivation for self-driven continuous programming practice by the students (see sections 4.3.1.1 and 4.3.1.2). To achieve this, the lecturer is expected closely monitor the students' activities online to moderate, scaffold and facilitate the process for students engagement as maintained by (Zhu, Yu, & Riezebos, 2016; Simpson, 2016)

The conducive individual-driven nature of the virtual lab environment is an advantage for introverts' learners to expressed themselves, share

ideas with colleagues and also interact with their educator unlike in physical lab (see section 4.3.2.2). Therefore, it can be said that the teaching and learning practice evidence in the virtual lab include: 1) students' ability to perform hands-on programming practice independently online anywhere using private computers and mobile devices; 2) the educator ability to scaffold on students' practical programming activities with feedbacks either synchronously or asynchronously (see sections 4.3.1.1 and 4.3.1.2); 3) use of online collaboration, problem-based learning, inquiry-based learning, experiential learning, and constructivist learning as pedagogical approaches; 4) demand for the educator to closely communicate and monitor the learning process online.

### **5.3 Conclusion**

In this study, a virtual lab environment was used to conduct hands-on Java programming activities in response to the challenge of limited computers in the physical computer lab and the BYOT policy constraint. The programming activities were conducted for three weeks with the participating students and the lecturer who created and assigned the lab activities to the students. The virtual lab activities include Java program coding, program testing, program debugging, and participants' interactions using chats and forum. After the activities, an interview was conducted for both students and the lecturer.

The purpose of this research study was to investigate how use of virtual lab as an emerging technology (in the context of UniJos) to conduct hands-on programming sessions with focus on Java programming language course could mediate students' programming

skills acquisition. The main objective of the study was to find out how could use of a virtual lab mediate Java programming skills acquisition amongst computer science students?

The research findings (see sections 4.3.1.1 and 4.3.2.1) show that the artifact (virtual lab) provide the subjects (students) with access to lab environment to practice Java programming independently at their own pace using their technologies remotely. Therefore, this mediates the challenge of limited computers in physical computer lab (see sections 4.3.1.1 and 4.3.1.2) and as mentioned in 5.2.1, the virtual lab can be deploy to supplement or serve as alternative to physical lab.

It is quite interesting to note that the use of the virtual lab for Java programming activities can encouraged introverts learners to interact and share ideas with peers and the lecturer online as analysed in section 4.3.2.2. This is evident in the respondents' statements: *'Is an opportunity for shy students to express themselves too'*; *'... allow us as students to share ideas via chats and forum like this discussing the VPL experience'* shown on fig 4.37 snapshots. Also, it was found that the activity system engaged the learners into self-pace and constant programming practice that can enhance programming skills development. Therefore, this investigation showed that use of virtual lab could mediate students' Java programming skills acquisition through constant accessibility to the lab, purposeful use and guided constant programming practice.

#### **5.4 Recommendations for Further Research**

Recommendations for further research work in this area are provided below.

### **5.4.1 Further Research**

The purpose of this research was to investigate how use of virtual lab mediates students programming skills acquisition in Computer Science department of the university. The study was limited to one programming language, that is, Java programming activity system (hands-on Java programming language practice), which I believed is a good starting point for further research work with interest in using virtual lab as mediating tool to mediate teaching and learning of science and engineering courses.

The virtual lab is actually an emerging trend for UniJos computer science department; however, the theoretical framework used (i.e. AT) provides a useful lens to investigate human activity in this context. Also, the findings suggest areas of interest for future research, particularly how students perceived the historic-cultural and/or the socio-cultural features of the virtual lab activity system for hands-on learning engagement.

### **5.4.2 Recommendations**

The recommendations or suggestions given here are based on the experience acquired during this research work intervention at UniJos in Nigeria.

1. The virtual lab activity system is recommended for institutions with limited or no computer systems in physical computer labs
2. To ensure that the artifact (virtual lab) mediate the acquisition of programming skills, the educator should scaffold and provides the learners with instant feedbacks on their programming activities

3. It is also recommended that apart from the educator interacting with the learners, the activity system rules and guidelines should provide and allow horizontal interactions between the learners within the activity system community using media like chats and forums to share ideas

Outline below are other recommendations for domestication of virtual lab in computer science department of UniJos in Nigeria; however, it is also applicable to any institution with similar background.

1. The virtual lab is recommended for the department to serve as alternative to the traditional lab so that all lecturers should be able to conduct hands-on programming sessions for all their programming courses.
2. The virtual lab is recommended to the department for its cost effectiveness and affordance compare to setting up physical computer lab with necessary facilities.
3. The virtual lab concept is recommended for exploration by all science and engineering departments in the entire UniJos. This will help the departments to improvised ways of conducting practical activities and exposed students to constructing their knowledge through self-experimentation.

Also, there are necessary technical design requirements to ensure proper functionality and performance of the virtual lab environment. These technical requirements include:

1. **Moodle LMS Requirements** – You need to install and configure Moodle LMS (or any other LMS) if it does not exist; installation of recent version at any time is preferred. For a fresh installation, check the Moodle server requirements both in terms of hardware and

software dependencies. The server operating system is not a dependable requirement since the Moodle can work on any operating system.

2. **Virtual Programming Lab (VPL) Plugin Installation and Configuration** – The VPL is a free add-on plugin compatible with Moodle LMS that you need to install and configure on the Moodle server as one of the LMS activity modules. This plugin provides the web-based interface of the virtual lab and it interacts with the compilers in the jail server (programs execution server) when a user tries to run or test a program. You can find the VPL download at <http://vpl.dis.ulpgc.es/index.php/home/download>
3. **The Jail Server Installation and Configuration** – The jail or execution server is very important and a must to be installed and configured on a separate server or inside a virtual machine depending on the require activities or number of expected compilers. The jail server installation include many compilers (e.g. Java compiler, C++ compiler, Python compiler, and others) and you can select them base on your needs. You can install more than one jail server depending on the processing requirements or expected execution traffic. If the appropriate parameters are configured in both the VPL and the jail server, the jail server(s) enables the execution of program codes in a console window similar to the usual compiler environment. Details of the ‘how-to’ can be found at <http://vpl.dis.ulpgc.es/index.php/support>

These are the major components needed to provide a good virtual lab for programming languages. It is worth noting that these installations and configurations are better performed or setup by a Network or

System Administrator who have the know-how to configure and deployed your virtual lab to be accessible either on an intranet, Internet or both.



## References

- Acheampong, P. (2013). *Employers' perception Of Graduates With Entry-Level Technical Skills From Construction Industry Programs In Ghana And Nigeria* (Doctoral dissertation, The Pennsylvania State University). Available online: <https://etda.libraries.psu.edu/paper/16922/15971> [January 15, 2016]
- Aguayo, C. (2016). Activity Theory and Online Community Education for Sustainability. In *Activity Theory in Education* (pp. 139-151). SensePublishers. [https://link.springer.com/chapter/10.1007/978-94-6300-387-2\\_9](https://link.springer.com/chapter/10.1007/978-94-6300-387-2_9) [September 19, 2017]
- Al-Adwan, A., & Smedley, J. (2013). Exploring students acceptance of e-learning using Technology Acceptance Model in Jordanian universities Amer Al-Adwan Applied Science University, Jordan. *International Journal of Education and Development using Information and Communication Technology*, 9(2), 4-18. Available online <http://ijedict.dec.uwi.edu/include/getdoc.php?id=5522> [January 20, 2016]
- Alkhaldi, T., Pranata, I., & Athauda, R. I. (2016). A review of contemporary virtual and remote laboratory implementations: observations and findings. *Journal of Computers in Education*, 3(3), 329-351. <https://link.springer.com/article/10.1007/s40692-016-0068-z> [September 17, 2017]
- Archibong, I. A., Oshiomu, A. O., & Bassey, S. (2010). Quality of Education Delivery: Trainer's Perspectives in Universities of Calabar and Uyo, Nigeria. *European Journal of Educational Studies*, 2(3). Available online: [http://ozelacademy.com/EJES\\_v2n3\\_3.pdf](http://ozelacademy.com/EJES_v2n3_3.pdf) [February 4, 2016]
- Bagarukayo, E., Ssentamu, P., Mayisela, T., & Brown, C. (2016). Activity Theory as a lens to understand how Facebook develops knowledge application skills. *International Journal of Education and Development using Information and Communication Technology*, 12(3), 128. <http://files.eric.ed.gov/fulltext/EJ1124826.pdf> [September 5, 2017]
- Barker, D., Quennerstedt, M., & Annerstedt, C. (2013). Inter-student interactions and student learning in health and physical education: A post-Vygotskian analysis. *Physical Education and Sport Pedagogy*, (ahead-of-print), 1-18. Available online

<http://www.tandfonline.com/doi/abs/10.1080/17408989.2013.868875> [January 12, 2016]

- Baruah, B., Ward, T., & Brereton, J. (2017). An e-learning tool for reflective practice and enhancing employability among engineering students. In *the 27th European Association for Education in Electrical and Information Engineering Annual Conference, EAEEIE* (pp. 7-9). [https://www.researchgate.net/profile/Bidyut\\_Baruah2/publication/317597308\\_An\\_e-learning\\_tool\\_for\\_reflective\\_practice\\_and\\_enhancing\\_employability\\_among\\_engineering\\_students/links/59424e2baca272a87300dff/An-e-learning-tool-for-reflective-practice-and-enhancing-employability-among-engineering-students.pdf](https://www.researchgate.net/profile/Bidyut_Baruah2/publication/317597308_An_e-learning_tool_for_reflective_practice_and_enhancing_employability_among_engineering_students/links/59424e2baca272a87300dff/An-e-learning-tool-for-reflective-practice-and-enhancing-employability-among-engineering-students.pdf) [September 20, 2017]
- Behrend, M. (2014). Engeström's activity theory as a tool to analyse online resources embedding academic literacies. *Journal of Academic Language and Learning*, 8(1), A109-A120. Available online: <http://journal.aall.org.au/index.php/jall/article/download/315/192> [May 21, 2016]
- Berenguel, M., Rodríguez, F., Moreno, J. C., Guzmán, J. L., & González, R. (2016). Tools and methodologies for teaching robotics in computer science & engineering studies. *Computer Applications in Engineering Education*, 24(2), 202-214. <http://http://onlinelibrary.wiley.com/doi/10.1002/cae.21698/full> [September 19, 2017]
- Bose, R. (2013). Virtual labs project: A paradigm shift in internet-based remote experimentation. *IEEE access*, 1, 718-725. Available online: <http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6637004> [July 2, 2016]
- Bowlick, F. J., Goldberg, D. W., & Bednarz, S. W. (2017). Computer Science and programming courses in Geography Departments in the United States. *The Professional Geographer*, 69(1), 138-150. <http://www.tandfonline.com/doi/abs/10.1080/00330124.2016.1184984> [September 19, 2017]
- Bozalek, V., Ng'ambi, D., Wood, D., Herrington, J., Hardman, J., & Amory, A. (Eds.). (2015). *Activity Theory, Authentic Learning and Emerging Technologies: Towards a Transformative Higher Education Pedagogy*.

Routledge. Available online: <http://preview.tinyurl.com/jjfay7e> [January 13, 2016]

Bravo Olavarria, R. A. (2013). Using cultural-historical activity theory (CHAT) to study the relationship between school leadership and organisational change. Available online: [http://eprints.qut.edu.au/63005/1/Renzo\\_Olavarria\\_Thesis.pdf](http://eprints.qut.edu.au/63005/1/Renzo_Olavarria_Thesis.pdf) [September 2, 2016]

Bringula, R. P., Balcoba, A. C., & Basa, R. S. (2016, May). Employable Skills of Information Technology Graduates in the Philippines: Do Industry Practitioners and Educators have the Same View?. In *Proceedings of the 21st Western Canadian Conference on Computing Education* (p. 10). ACM. <http://dl.acm.org/citation.cfm?id=2910928> [September 20, 2017]

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. *Computers & Education*, 87, 218-237. <http://www.sciencedirect.com/science/article/pii/S0360131515300087> (September 1, 2017)

Çakiroglu, Ü., Kokoç, M., Kol, E., & Turan, E. (2016). Exploring teaching programming online through web conferencing system: The lens of activity theory. *Journal of Educational Technology & Society*, 19(4), 126. [www.ifets.info/journals/19\\_4/11.pdf](http://www.ifets.info/journals/19_4/11.pdf) [September 5, 2017]

Chen, B., DeMara, R. F., Salehi, S., & Hartshorne, R. (2017). Elevating Learner Achievement Using Formative Electronic Lab Assessments in the Engineering Laboratory: A Viable Alternative to Weekly Lab Reports. *IEEE Transactions on Education*. <http://ieeexplore.ieee.org/abstract/document/7940018/> [September 20, 2017]

Chen, X., Song, G., & Zhang, Y. (2010). Virtual and Remote Laboratory Development: A Review. *Earth and Space 2010: Engineering, Science, Construction, and Operations in Challenging Environments*. Available online: <http://engineeringtech.tsu.edu/~xchen/documents/368.pdf> [February 4, 2016]

- Cheng, W., Chen, P., Liu, X., & Huang, R. (2016, July). Designing Authentic Learning to Meet the Challenges of Digital Natives in First-Year Program: An Action Research in Chinese University. In *Advanced Learning Technologies (ICALT), 2016 IEEE 16th International Conference on* (pp. 453-454). IEEE. <http://http://ieeexplore.ieee.org/abstract/document/7757021/> [September 17, 2017]
- Clark, R. C., & Mayer, R. E. (2011). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning*. John Wiley & Sons. Available online: <http://preview.tinyurl.com/hdtk7eh> [January 15, 2016]
- Clarke, V., & Braun, V. (2014). Thematic analysis. In *Encyclopedia of critical psychology* (pp. 1947-1952). Springer New York. [https://link.springer.com/referenceworkentry/10.1007%2F978-1-4614-5583-7\\_311](https://link.springer.com/referenceworkentry/10.1007%2F978-1-4614-5583-7_311) [September 3, 2017]
- Clemmensen, T., Kaptelinin, V., & Nardi, B. (2016). Making HCI theory work: an analysis of the use of activity theory in HCI research. *Behaviour & Information Technology*, 35(8), 608-627. [www.artifex.org/~bonnie/Clemmensen\\_et\\_al.%20BIT\\_2016%20copy.pdf](http://www.artifex.org/~bonnie/Clemmensen_et_al.%20BIT_2016%20copy.pdf) [September 17, 2017]
- Cook, W. R. (2013). Anatomy of Programming Languages. *Evaluation*, 3, 7. Available online: [www.cs.utexas.edu/~wcook/anatomy/anatomyVerbatim.pdf](http://www.cs.utexas.edu/~wcook/anatomy/anatomyVerbatim.pdf) [January 16, 2016]
- Cordeiro, R., Fonseca, J. M., & Alves, G. R. (2015, October). Evolutionary analysis of online labs. In *Proceedings of the 3rd International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 631-637). ACM. <http://dl.acm.org/citation.cfm?id=2808677> [September 1, 2017]
- Dawson, C. (2009). *Introduction to research methods: A practical guide for anyone undertaking a research project*. Hachette UK.
- Diwakar, S., Kumar, D., Radhamani, R., Sasidharakurup, H., Nizar, N., Achuthan, K., ... & Nair, B. (2016). Complementing Education via Virtual Labs: Implementation and Deployment of Remote Laboratories

- and Usage Analysis in South Indian Villages. *International Journal of Online Engineering*, 12(3).  
[https://www.researchgate.net/profile/Dhanush\\_Kumar2/publication/294718675\\_Complementing\\_Education\\_via\\_Virtual\\_Labs\\_Implementation\\_and\\_Deployment\\_of\\_Remote\\_Laboratories\\_and\\_Usage\\_Analysis\\_in\\_South\\_Indian\\_Villages/links/56fe0c1408ae1408e15b3c67/Complementing-Education-via-Virtual-Labs-Implementation-and-Deployment-of-Remote-Laboratories-and-Usage-Analysis-in-South-Indian-Villages.pdf](https://www.researchgate.net/profile/Dhanush_Kumar2/publication/294718675_Complementing_Education_via_Virtual_Labs_Implementation_and_Deployment_of_Remote_Laboratories_and_Usage_Analysis_in_South_Indian_Villages/links/56fe0c1408ae1408e15b3c67/Complementing-Education-via-Virtual-Labs-Implementation-and-Deployment-of-Remote-Laboratories-and-Usage-Analysis-in-South-Indian-Villages.pdf)  
 [September 17, 2017]
- Dunn, L. (2017). Enabling peer-to-peer collaboration within online learning environments and virtual laboratories. *Scottish Technology Teachers Association*. <http://eprints.gla.ac.uk/136751/1/136751.pdf> [September 18, 2017]
- Encalada, W. L., & Sequera, J. L. C. (2017). Model to Implement Virtual Computing Labs via Cloud Computing Services. *Symmetry*, 9(7), 117. <http://www.mdpi.com/2073-8994/9/7/117/htm> [September 2, 2017]
- Engeström, Y. (2014). *Learning by expanding*. An Activity-Theoretical Approach to Developmental Research, Second Edition. Cambridge University Press. Available online: <http://preview.tinyurl.com/hatyy3o> [January 12, 2016]
- Engeström, Y. (2017a). Expanding the scope of science education: an activity-theoretical perspective. In *Cognitive and Affective Aspects in Science Education Research* (pp. 357-370). Springer, Cham. [https://link.springer.com/chapter/10.1007/978-3-319-58685-4\\_26](https://link.springer.com/chapter/10.1007/978-3-319-58685-4_26) [September 19, 2017]
- Engeström, Y. (2017b). Conflict and Curiosity: The Legacy of Naoki Ueno. *Mind, Culture, and Activity*, 24(2), 146-149. <http://www.tandfonline.com/doi/abs/10.1080/10749039.2017.1308515> [September 19, 2017]
- Ernst, M. D. (2017). Natural language is a programming language: Applying natural language processing to software development. In *LIPICs-Leibniz International Proceedings in Informatics* (Vol. 71). Schloss Dagstuhl-

Leibniz-Zentrum fuer Informatik.  
<http://drops.dagstuhl.de/opus/volltexte/2017/7135/> [September 20, 2017]

Farooq, M. & Khalid, H., (2013). LMS and Virtual Labs for Engineering Education. *Academy of Contemporary Research Journal*, Volume II, Issue IV, 2013, 171 -174. Available online: <http://aocrj.org/wp-content/uploads/2013/10/AOCRJ-V2I4P4-LMS-and-Virtual-Labs.pdf> [July 4, 2016]

Fernández, C., Vicente, M. A., Galotto, M., Martinez-Rach, M., & Pomares, A. (2017). Improving student engagement on programming using app development with Android devices. *Computer Applications in Engineering Education*.  
<http://onlinelibrary.wiley.com/doi/10.1002/cae.21827/full>  
[September 18, 2017]

Frerich, S., Kruse, D., Petermann, M., & Kilzer, A. (2016). Virtual labs and remote labs: Practical experience for everyone. In *Engineering Education 4.0* (pp. 229-234). Springer International Publishing.  
[https://link.springer.com/chapter/10.1007/978-3-319-46916-4\\_18](https://link.springer.com/chapter/10.1007/978-3-319-46916-4_18)  
[September 17, 2017]

Furberg, A. (2016). Teacher support in computer-supported lab work: Bridging the gap between lab experiments and students' conceptual understanding. *International Journal of Computer-Supported Collaborative Learning*, 11(1), 89-113.  
<https://link.springer.com/article/10.1007/s11412-016-9229-3>  
[September 17, 2017]

Galan, D., Heradio, R., de la Torre, L., Dormido, S., & Esquembre, F. (2016, February). Automated experiments on EjsS laboratories. In *Remote Engineering and Virtual Instrumentation (REV), 2016 13th International Conference on* (pp. 78-85). IEEE.  
<http://ieeexplore.ieee.org/abstract/document/7444444/> [September 19, 2017]

Galan, D., Heradio, R., de la Torre, L., Dormido, S., & Esquembre, F. (2017). The experiment editor: supporting inquiry-based learning with virtual labs. *European Journal of Physics*, 38(3), 035702.  
<http://iopscience.iop.org/article/10.1088/1361-6404/aa5dc1/meta>  
[September 1, 2017]

- Gosling, J., Joy, B., Steele Jr, G. L., Bracha, G., & Buckley, A. (2014). *The Java Language Specification*. Addison-Wesley Professional. Available online: <http://preview.tinyurl.com/j6qpzcb> [January 16, 2016]
- Gray, D. E. (2013). *Doing research in the real world*. Sage. Available online: [www.sagepub.in/upm-data/58626\\_Gray\\_Doing\\_Research\\_in\\_the\\_Real\\_World.pdf](http://www.sagepub.in/upm-data/58626_Gray_Doing_Research_in_the_Real_World.pdf) [January 20, 2016]
- Gros, B. (2016). The design of smart educational environments. *Smart Learning Environments*, 3(1), 15. <http://diposit.ub.edu/dspace/handle/2445/107883> [September, 17, 2017]
- Hardman, J. (2005), Activity Theory as a Framework for Understanding Teachers' Perceptions of Computer Usage at a Primary School level in South Africa. *South African Journal of Education*, 25(4), 258-265. Available online: [www.ajol.info/index.php/saje/article/download/25046/20717](http://www.ajol.info/index.php/saje/article/download/25046/20717) [February 4, 2016]
- Heradio, R., de la Torre, L., & Dormido, S. (2016). Virtual and remote labs in control education: A survey. *Annual Reviews in Control*, 42, 1-10. <http://www.sciencedirect.com/science/article/pii/S1367578816300281> [September 17, 2017]
- Heradio, R., de la Torre, L., Galan, D., Cabrerizo, F. J., Herrera-Viedma, E., & Dormido, S. (2016). Virtual and remote labs in education: A bibliometric analysis. *Computers & Education*, 98, 14-38. <http://www.sciencedirect.com/science/article/pii/S0360131516300677> [September 1, 2017]
- Hovardas, T., Xenofontos, N. A., & Zacharia, Z. C. (2017). Using Virtual Labs in an Inquiry Context: The Effect of. *Optimizing STEM Education With Advanced ICTs and Simulations*, 58. [https://books.google.com.ng/books?hl=en&lr=&id=wBknDwAAQBAJ&oi=fnd&pg=PA58&dq=affordances+of+virtual+lab&ots=6EacPzAS0Z&sig=knMss8oWtSkYCUeoKEI9igZRI40&redir\\_esc=y#v=onepage&q=interactive&f=false](https://books.google.com.ng/books?hl=en&lr=&id=wBknDwAAQBAJ&oi=fnd&pg=PA58&dq=affordances+of+virtual+lab&ots=6EacPzAS0Z&sig=knMss8oWtSkYCUeoKEI9igZRI40&redir_esc=y#v=onepage&q=interactive&f=false) [September 19, 2017]
- Hidayat, A., & Utomo, V. G. (2015). Virtual Laboratory Implementation To Support High School Learning. *International Journal of Computer Applications*, 120(16). Available online:

<http://search.proquest.com/openview/f948a12af5c212c5dfa7eba10f3338cb/1?pq-origsite=gscholar> [January 18, 2016]

Jaffer, S., Ng'ambi, D. & Czemiewicz, C. (2007). The role of ICTs in higher education in South Africa: One strategy for addressing teaching and learning challenges. *International Journal of Education and Development using Information and Communication Technology (IJEDICT)*, 3(4), 131-142. Available online: <http://ijedict.dec.uwi.edu/viewarticle.php?id=421> [February 1, 2016]

Johns-Boast, L. (2014). Developing Personal and Professional Skills in Software Engineering Students. *Overcoming Challenges in Software Engineering Education: Delivering Non-Technical Knowledge and Skills*, 198-228. Available online: <http://preview.tinyurl.com/hxux94p> [January 15, 2016]

Jos-Carnegie Partnership Project (2006). *The History of Information and Communication Technology at the University of Jos*. Fab Educational Books, Jos, Nigeria. ISBN 978-8039-36-7

Juhary, J. (2014). Perceived usefulness and ease of use of the learning management system as a learning tool. *International Education Studies*, 7(8), p23. Available online: [www.ccsenet.org/journal/index.php/ies/article/download/36152/21561](http://www.ccsenet.org/journal/index.php/ies/article/download/36152/21561) [January 20, 2016]

Kaunang, S. T. G., Paturusi, S. D., Usagawa, T., Mangindaan, G., Sambul, A., & Sugiarto, B. (2016, October). Student perceptions of virtual programming lab on e-learning class at University of Sam Ratulangi. In *Information & Communication Technology and Systems (ICTS), 2016 International Conference on* (pp. 244-248). IEEE. <http://ieeexplore.ieee.org/document/7910306/> [September 2, 2017]

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. Pearson Education. Available online: <http://academic.regis.edu/ed205/kolb.pdf> [January 15, 2016]

- Kori, K., Pedaste, M., Leijen, Ä., & Tõnisson, E. (2016). The role of programming experience in ICT students' learning motivation and academic achievement. *International Journal of Information and Education Technology*, 6(5), 331. [https://www.researchgate.net/profile/Eno\\_Tonisson/publication/276485030\\_The\\_Role\\_of\\_Programming\\_Experience\\_in\\_ICT\\_Students'\\_Learning\\_Motivation\\_and\\_Academic\\_Achievement/links/55e15a8708aede0b5730416c.pdf](https://www.researchgate.net/profile/Eno_Tonisson/publication/276485030_The_Role_of_Programming_Experience_in_ICT_Students'_Learning_Motivation_and_Academic_Achievement/links/55e15a8708aede0b5730416c.pdf) [September 20, 2017]
- Lemons, C., et al (2012). Educational Analysis and Physical Implementation of a Remote Lab. Worcester Polytechnic Institute. Available online: [http://www.wpi.edu/Pubs/E-project/Available/E-project-042512-145745/unrestricted/MQP\\_Report.pdf](http://www.wpi.edu/Pubs/E-project/Available/E-project-042512-145745/unrestricted/MQP_Report.pdf) [January 19, 2016]
- Leonardo, Z., & Manning, L. (2017). White historical activity theory: toward a critical understanding of white zones of proximal development. *Race Ethnicity and Education*, 20(1), 15-29. <http://www.tandfonline.com/doi/abs/10.1080/13613324.2015.1100988> [September 19, 2017]
- Lewis, D. I. (2014). The pedagogical benefits and pitfalls of virtual tools for teaching and learning laboratory practices in the biological sciences. *The Higher Education Academy: STEM*. Available online: [https://www.heacademy.ac.uk/sites/default/files/resources/the\\_pedagogical\\_benefits\\_and\\_pitfalls\\_of\\_virtual\\_tools\\_for\\_teaching\\_and\\_learning\\_laboratory\\_practices\\_in\\_the\\_biological\\_sciences.pdf](https://www.heacademy.ac.uk/sites/default/files/resources/the_pedagogical_benefits_and_pitfalls_of_virtual_tools_for_teaching_and_learning_laboratory_practices_in_the_biological_sciences.pdf) [July 2, 2016]
- Loeb, S., Dynarski, S., McFarland, D., Morris, P., Reardon, S., & Reber, S. (2017). Descriptive Analysis in Education: A Guide for Researchers. NCEE 2017-4023. *National Center for Education Evaluation and Regional Assistance*. <https://eric.ed.gov/?id=ED573325> [September 4, 2017]
- Mäkynen, A. (2012). A Picture is Worth a Thousand Words-or Is It? The Interplay of Text and Images in Technical Documents. Available online: <https://tampub.uta.fi/bitstream/handle/10024/83503/gradu05861.pdf?sequence=1> [January 24, 2016]

- Mauro, M. H., Ohashi, F. K., Gaspar, M. A., & de Magalhães, F. L. F. (2017, May). Contribution of Learning Management System (LMS) to the Corporate Knowledge Management. In *14th CONTECSI-International Conference on Information Systems and Technology Management*.  
<http://www.contecsi.fea.usp.br/envio/index.php/contecsi/14CONTECSI/paper/viewPaper/4644> [September 20, 2017]
- Maxwell, J. A. (2008). Designing a qualitative study. *The SAGE handbook of applied social research methods*, 2, 214-253.  
[http://www.corwin.com/upm-data/23772\\_Ch7.pdf](http://www.corwin.com/upm-data/23772_Ch7.pdf) [September 4, 2017]
- Maxwell, J. A. (2012:P.139). *Qualitative research design: An interactive approach* (Vol. 41). Sage publications.  
<http://theballadeersscotland.com/juqibem.pdf> (September 4, 2017)
- Mlitwa, N. & Van Belle J. P. (2011) Mediators for Lecturer Perspectives on Learning Management Systems at Universities in the Western Cape, South Africa. Proceedings of the PACIS 2011 conference, Brisbane, Australia (AISLibrary). ISBN: 978-1-86435-644-1; Publisher: Queensland University of Technology. Available online: [www.pacis-net.org/file/2011/PACIS2011-131.pdf](http://www.pacis-net.org/file/2011/PACIS2011-131.pdf) [January 27, 2016]
- Navaraja, A. T., Jain, N., Sengupta, D., & Kumar, C. S. (2016). Web based simulation and remote triggered laboratory for robots. In *CAD/CAM, Robotics and Factories of the Future* (pp. 665-677). Springer, New Delhi. [https://link.springer.com/chapter/10.1007/978-81-322-2740-3\\_64](https://link.springer.com/chapter/10.1007/978-81-322-2740-3_64) [September 19, 2017]
- Noesgaard, S. S., & Ørngreen, R. (2015). The effectiveness of e-learning: an explorative and integrative review of the definitions, methodologies and factors that promote e-learning effectiveness. *Electronic Journal of e-Learning*, 13(4), 278-290.  
[http://vbn.aau.dk/ws/files/212383260/EJEL\\_volume13\\_issue4\\_article410\\_Noesgaard\\_rngreen.pdf](http://vbn.aau.dk/ws/files/212383260/EJEL_volume13_issue4_article410_Noesgaard_rngreen.pdf) [September 4, 2017]
- Oliveira, T. A., Marranghello, N., Silva, A. C. R., & Pereira, A. S. (2016). Virtual Laboratories Development Using 3D Environments. In *Handbook of Research on 3-D Virtual Environments and Hypermedia for Ubiquitous Learning* (pp. 29-53). IGI Global.  
<https://books.google.com.ng/books?hl=en&lr=&id=VNk6DAAAQBAJ&oi=fnd&pg=PA29&dq=In+1997,+the+first+version+of+the+Virtual+>

[Laboratory+was+presented,+titled+Virtual+Laboratory+of+Physiology.+&ots=avK7qFJkCw&sig=5bXgPhITIJ-kVf4HYD1PgDQmEoo&redir\\_esc=y#v=onepage&q&f=false](#)  
[September 17,2017]

Pellas, N., Kazanidis, I., Konstantinou, N., & Georgiou, G. (2017). Exploring the educational potential of three-dimensional multi-user virtual worlds for STEM education: A mixed-method systematic literature review. *Education and Information Technologies*, 22(5), 2235-2279. <https://link.springer.com/article/10.1007/s10639-016-9537-2> [September 19, 2017]

Pelet, J. E., Khan, J., Papadopoulou, P., & Bernardin, E. (2015). M-Learning: Exploring the Use of Mobile. *Human-Computer Interaction: Concepts, Methodologies, Tools, and Applications: Concepts, Methodologies, Tools, and Applications*, 256. Available online: <http://preview.tinyurl.com/zmqx3c4> [February 1, 2016]

Petrović, V. M., Nikolić, B., Jovanović, K., & Potkonjak, V. (2016, June). Development of Virtual Laboratory for Mechatronic Systems. In *International Conference on Robotics in Alpe-Adria Danube Region* (pp. 622-630). Springer International Publishing. [https://link.springer.com/chapter/10.1007/978-3-319-49058-8\\_68](https://link.springer.com/chapter/10.1007/978-3-319-49058-8_68)  
[September 17, 2017]

Pisani, P. H., & Carvalho, A. C. P. D. L. (2017). Applying the Virtual Programming Lab with Python. [http://repositorio.icmc.usp.br/bitstream/handle/RIICMC/6612/RELATORIOS\\_TECNICOS\\_ICMC\\_419\\_2017.pdf?sequence=1](http://repositorio.icmc.usp.br/bitstream/handle/RIICMC/6612/RELATORIOS_TECNICOS_ICMC_419_2017.pdf?sequence=1) [September 19, 2017]

Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education*, 95, 309-327. [https://www.researchgate.net/profile/Kosta\\_Jovanovic2/publication/294423099\\_Virtual\\_Laboratories\\_for\\_Education\\_in\\_Science\\_Technology\\_and\\_Engineering\\_a\\_Review/links/587dde0208aed3826af29b2b/Virtual-](https://www.researchgate.net/profile/Kosta_Jovanovic2/publication/294423099_Virtual_Laboratories_for_Education_in_Science_Technology_and_Engineering_a_Review/links/587dde0208aed3826af29b2b/Virtual-)

[Laboratories-for-Education-in-Science-Technology-and-Engineering-a-Review.pdf](#) [September 17, 2017]

- Pulido, L. X. V., Villamil, N. O., & Tarazona, G. (2017, August). E-Learning Platforms Analysis for Encourage Colombian Education. In *International Conference on Knowledge Management in Organizations* (pp. 107-118). Springer, Cham. [https://link.springer.com/chapter/10.1007/978-3-319-62698-7\\_10](https://link.springer.com/chapter/10.1007/978-3-319-62698-7_10) [September 20, 2017]
- Qvist, P., Kangasniemi, T., Palomäki, S., Seppänen, J., Joensuu, P., Natri, O., ... & Nordström, K. (2015). Design of Virtual Learning Environments: Learning Analytics and Identification of Affordances and Barriers. *International Journal of Engineering Pedagogy (iJEP)*, 5(4), 64-75. <http://online-journals.org/index.php/i-jep/article/view/4962> [September 19, 2017]
- Rautkorpi, T., & Hero, L. M. (2016). Promoting students' reflections in organisational improvisation arrangement between higher education and workplaces. *Nordic Journal of Vocational Education and Training*, 7(1), 1-22. [www.njvet.ep.liu.se/issues/2017/v7/i1/02/njvet\\_17v7i1a2.pdf](http://www.njvet.ep.liu.se/issues/2017/v7/i1/02/njvet_17v7i1a2.pdf) (September 16, 2017)
- Robinson, P. E., & Carroll, J. (2017, April). An online learning platform for teaching, learning, and assessment of programming. In *Global Engineering Education Conference (EDUCON), 2017 IEEE* (pp. 547-556). IEEE. <http://ieeexplore.ieee.org/abstract/document/7942900/> [September 19, 2017]
- Roth, W. M. (2014). Zone of Proximal Development. In *Encyclopedia of Critical Psychology* (pp. 2101-2105). Springer New York. Available online: [http://link.springer.com/referenceworkentry/10.1007/978-1-4614-5583-7\\_334](http://link.springer.com/referenceworkentry/10.1007/978-1-4614-5583-7_334) [January 12, 2016]
- Sannino, A., Engeström, Y., & Lemos, M. (2016). Formative interventions for expansive learning and transformative agency. *Journal of the Learning Sciences*, 25(4), 599-633. [https://helda.helsinki.fi/bitstream/handle/10138/178032/SEL\\_Formative\\_Interventions\\_for\\_Expansive\\_Learning\\_and\\_Transformative\\_Agency.pdf?sequence=1](https://helda.helsinki.fi/bitstream/handle/10138/178032/SEL_Formative_Interventions_for_Expansive_Learning_and_Transformative_Agency.pdf?sequence=1) [September 5, 2017]
- Savić, M., Ivanović, M., Budimac, Z., & Radovanović, M. (2016, June). Do students' programming skills depend on programming language?. In *AIP Conference Proceedings* (Vol. 1738, No. 1, p. 240006). AIP

Publishing. <http://http://aip.scitation.org/doi/abs/10.1063/1.4952025>  
[September 19, 2017]

Simpson, J. (2016). Authentic Learning-Does it Improve Pass Rates and Student Satisfaction?. *Journal of Perspectives in Applied Academic Practice*, 4(2), 62-70. <http://eprints.leedsbeckett.ac.uk/2622/> [September 3, 2017]

Smith-Glaviana, D. C. (2016). Inconspicuous Fandom: Exploring Subtle Female's Expressions of Science Fiction and Fantasy Fandom through Dress. [http://digitalcommons.lsu.edu/cgi/viewcontent.cgi?article=4084&context=gradschool\\_dissertations](http://digitalcommons.lsu.edu/cgi/viewcontent.cgi?article=4084&context=gradschool_dissertations) [September 4, 2017]

Soni, M. S., & Katkar, M. D. (2014). Survey paper on Virtual Lab for E-Learners. *International Journal of Application or Innovation in Engineering & Management (IJAIEM)*. Volume 3, Issue 1, January 2014. Available online: <http://ijaiem.org/volume3issue1/IJAIEM-2014-01-13-027.pdf> [July 2, 2016]

Šorgo, A., Bartol, T., Dolničar, D., & Boh Podgornik, B. (2017). Attributes of digital natives as predictors of information literacy in higher education. *British Journal of Educational Technology*, 48(3), 749-767. <http://http://onlinelibrary.wiley.com/doi/10.1111/bjet.12451/full>  
[September 18, 2017]

Su, C. H., Tzeng, G. H., & Hu, S. K. (2016). Cloud e-learning service strategies for improving e-learning innovation performance in a fuzzy environment by using a new hybrid fuzzy multiple attribute decision-making model. *Interactive Learning Environments*, 24(8), 1812-1835. <http://www.tandfonline.com/doi/abs/10.1080/10494820.2015.1057742>  
[September 20, 2017]

- Talanquer, V. (2014). Using qualitative analysis software to facilitate qualitative data analysis. *Tools of Chemistry Education Research*, 1166. Available online: [http://http://cbc.arizona.edu/tpp/ACS\\_ToolsCEd14.pdf](http://http://cbc.arizona.edu/tpp/ACS_ToolsCEd14.pdf) [November 27, 2016]
- Tatli, Z., & Ayas, A. (2013). Effect of a Virtual Chemistry Laboratory on Students' Achievement. *Educational technology & society*, 16(1), 159-170. Available online: <http://www.jstor.org/tc/accept?origin=/stable/pdf/jeductechsoci.16.1.159.pdf> [July 2, 2016]
- Taylor, A. (2014). Community service-learning and cultural-historical activity theory. *The Canadian Journal of Higher Education*, 44(1), 95. Available online: [www.canlitsubmit.ca/index.php/cjhe/article/viewFile/183605/184420](http://www.canlitsubmit.ca/index.php/cjhe/article/viewFile/183605/184420) [May 21, 2016]
- Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2016). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*. Retrieved on September 19, 2017 from [https://www.researchgate.net/profile/Jo\\_Tondeur/publication/308128849\\_Understanding\\_the\\_relationship\\_between\\_teachers'\\_pedagogical\\_beliefs\\_and\\_technology\\_use\\_in\\_education\\_A\\_systematic\\_review\\_of\\_qualitative\\_evidence/links/583beeb108aed5c6148caced.pdf](https://www.researchgate.net/profile/Jo_Tondeur/publication/308128849_Understanding_the_relationship_between_teachers'_pedagogical_beliefs_and_technology_use_in_education_A_systematic_review_of_qualitative_evidence/links/583beeb108aed5c6148caced.pdf)[September 19, 2017]
- Unijos ICT Policy* (2008), Information and Communications Technology (ICT) Policy, University of Jos, Nigeria. Unpublished policy document at University of Jos.
- Villar, D., & Papoutsis, O. C. (2013). NVivo 10: Introductory course Nov 2013. [www.academia.edu/download/32349615/Villar-Onrubia\\_2013\\_NVivo\\_Workshop\\_Slides.pdf](http://www.academia.edu/download/32349615/Villar-Onrubia_2013_NVivo_Workshop_Slides.pdf) [November 27, 2016]

- Wang, H. (2012). Using Virtual Programming Lab for Web-based Distance Education. In T. Amiel & B. Wilson (eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2012*, 1745-1751). Chesapeake, VA: AACE. Available online: <http://www.editlib.org/p/40980> [September 19, 2017]
- Wang, H., and Philips, D. (2012) Implement Virtual Programming Lab with Cloud Computing for Web-Based Distance Education. Athabasca University, Canada. Available online: <http://www.irma-international.org/viewtitle/65288/> [February 8, 2016]
- Wilson, V. (2014) 'Examining teacher education through cultural historical activity theory', *Tean Journal* 6(1), pp. 20-29. Available online: <http://194.81.189.19/ojs/index.php/TEAN/article/view/180/294> [May 24, 2016]
- Zalewski, J., & Gonzalez, F. (2017). Evolution in the Education of Software Engineers: Online Course on Cyberphysical Systems with Remote Access to Robotic Devices. *International Journal of Online Engineering (iJOE)*, 13(08), 133-146. <http://www.online-journals.org/index.php/i-joe/article/view/7377> [September 18, 2017]
- Zhu, Z. T., Yu, M. H., & Riezebos, P. (2016). A research framework of smart education. *Smart Learning Environments*, 3(1), 4. <https://slejournal.springeropen.com/articles/10.1186/s40561-016-0026-2> [September 3, 2017]

## Appendices

### Appendix A: Snapshots of Students' Work & Submissions

[Submission](#)[Edit](#)[Submission view](#)[Grade](#)[Previous submissions list](#)

Submitted on Monday, 10 August 2015, 9:18 pm ([Download](#))

### Search Word in a String

```
1 public class SearchStringEmp{
2     public static void main(String[] args) {
3         String strOrig = "Hello readers";
4         int intIndex = strOrig.indexOf("Hello");
5         if(intIndex == - 1){
6             System.out.println("Hello not found");
7         }else{
8             System.out.println("Found Hello at index "
9                 + intIndex);
10        }
11    }
12 }
```

[Submission](#)[Edit](#)[Submission view](#)[Grade](#)[Previous submissions list](#)

Submitted on Thursday, 13 August 2015, 9:20 am ([Download](#))

## Summation of nth Numbers

```
1 import java.io.IOException;
2
3 public class AdditionStack {
4     static int num;
5     static int ans;
6     static Stack theStack;
7     public static void main(String[] args)
8     throws IOException {
9         num = 50;
10        stackAddition();
11        System.out.println("Sum=" + ans);
12    }
13    public static void stackAddition() {
14        theStack = new Stack(10000);
15        ans = 0;
16        while (num > 0) {
17            theStack.push(num);
18            --num;
19        }
20        while (!theStack.isEmpty()) {
21            int newN = theStack.pop();
22            ans += newN;
23        }
24    }
25 }
26
```

```
27 class Stack {
28     private int maxSize;
29     private int[] data;
30     private int top;
31     public Stack(int s) {
32         maxSize = s;
33         data = new int[maxSize];
34         top = -1;
35     }
36     public void push(int p) {
37         data[++top] = p;
38     }
39     public int pop() {
40         return data[top--];
41     }
42     public int peek() {
43         return data[top];
44     }
45     public boolean isEmpty() {
46         return (top == -1);
47     }
48 }
```


























[Submission](#)[Edit](#)[Submission view](#)[Grade](#)[Previous submissions list](#)

Submitted on Monday, 17 August 2015, 9:25 pm ([Download](#))

## Implementation of Stack




















```
1 public class MyStack {
2     private int maxSize;
3     private long[] stackArray;
4     private int top;
5     public MyStack(int s) {
6         maxSize = s;
7         stackArray = new long[maxSize];
8         top = -1;
9     }
10    public void push(long j) {
11        stackArray[++top] = j;
12    }
13    public long pop() {
14        return stackArray[top--];
15    }
16    public long peek() {
17        return stackArray[top];
18    }
19    public boolean isEmpty() {
20        return (top == -1);
21    }
22    public boolean isFull() {
23        return (top == maxSize - 1);
24    }
25    public static void main(String[] args) {
26        MyStack theStack = new MyStack(10);
27        theStack.push(10);
28        theStack.push(20);
29        theStack.push(30);
30        theStack.push(40);
31        theStack.push(50);
32        while (!theStack.isEmpty()) {
33            long value = theStack.pop();
34            System.out.print(value);
35            System.out.print(" ");
36        }
37        System.out.println("");
38    }
39 }
```

## Appendix B: How Lecturer Assigned Tasks in Virtual Lab

  Write a Java program that use method for calculating Fibonacci series 	Edit  
  Write a Java program that use method for calculating Factorial of a number 	Edit  
  Create Shapes with Applets 	Edit  
  Virtual Lab Experience 	Edit  
  Methods 	Edit  

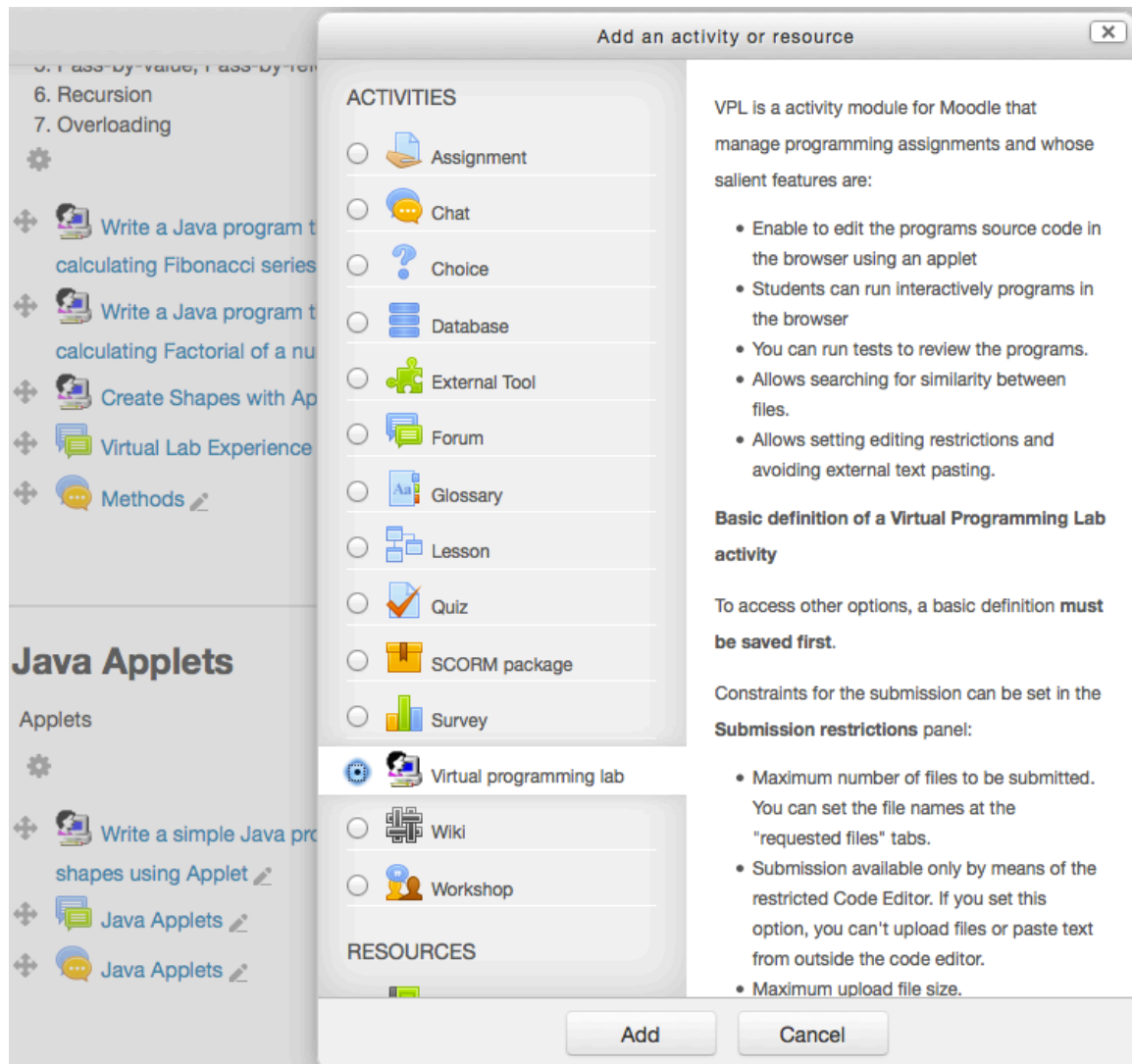
[+ Add an activity or resource](#)

---

 <b>Java Applets</b>  	
Applets	
	
  Write a simple Java program that create different shapes using Applet 	Edit  
  Java Applets 	Edit  
  Java Applets 	Edit  

[+ Add an activity or resource](#)

To assign task: Click on add an activity or resource then the window below will appear.



On the plugin's panel, select the Virtual programming lab and click on Add button, then the window below will appear enabling you to assign programming task.

## Adding a new Virtual programming lab to Methods

▶ Expand all

### ▼ General

**Name\***

**Short description**

**Full description**



Write a Java program that use method for calculating Fibonacci series

**Display description on course page**



### ▶ Submission period

### ▶ Submission restrictions

### ▶ Grade

### ▶ Common module settings

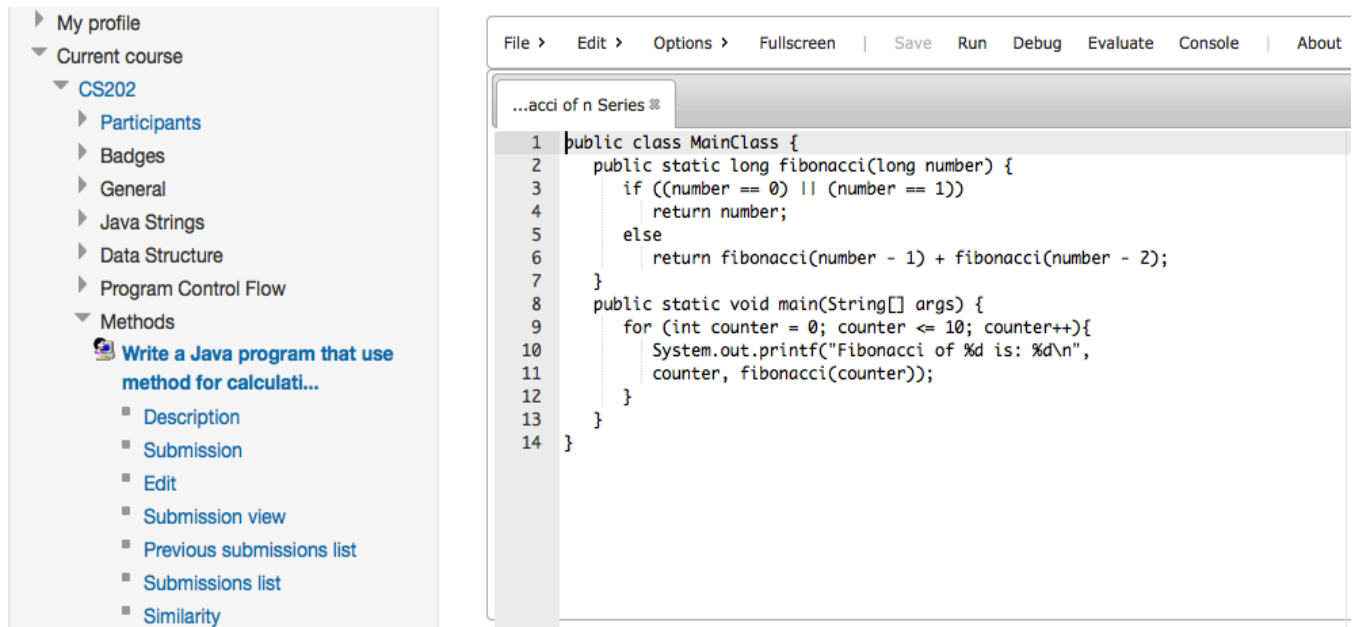
Save and return to course

Save and display

Cancel

There are required fields in this form marked \*.

## Appendix C: Visual Relationship Between LMS and Virtual Lab



LMS left panel and 'Virtual Lab' displayed as a window on LMS, on the right panel

The virtual lab is embedded on LMS using the VPL plugin to provide virtual lab as an activity resource on the LMS.

## Appendix D: Snapshots of Students Interview Transcription from Nvivo and Text Extracts

The screenshot displays the Nvivo software interface. The main window shows a transcription of an interview. The transcription is organized into segments, each with a start and end time, a transcript of the spoken text, and the name of the speaker. The interface also includes a sidebar with navigation options, a central audio player with a waveform, and a menu bar at the top.

Start Time	End Time	Transcript	Speaker
00:00:07.7	00:02:27.6	The virtual lab was very easy to access; however there was a network challenge i.e. the Internet connection. The virtual lab was very easy to use. The virtual lab is a good idea that enables me to practice program coding at leisure time and I actually work on my exercises while on transit. It is an opportunity to put down ideas in practice as they come at any time and encourages more practice; and I gain more skills on programming using the virtual lab. I prefer the virtual lab environment to the traditional lab because in virtual lab I am at ease unlike the tension attached to the normal traditional lab and in virtual lab environment I express myself better. I recommend improvement on the network quality.	Student1
00:02:27.7	00:05:08.1	The virtual lab was easy to access, however there was network problem. The virtual lab was easy and friendly to use. It is good and it will help students to practice program coding more. It is an opportunity to practice program coding and is a welcome development. I preferred and recommend the virtual lab because it can be access anywhere anytime compare to the traditional lab where every student has to come to the lab.	Student2
00:05:10.4	00:08:02.5	The virtual lab was quite easy to access by typing in my login details then instantly I was able to access the VPL environment. The virtual	Student3

1: Snapshots of Students Interview Transcription Inside Nvivo

Speaker: Student1

Transcript

The virtual lab was very easy to access; however there was a network challenge i.e. the Internet connection. The virtual lab was very easy to use. The virtual lab is a good idea that enables me to practice program coding at leisure time and I actually work on my exercises while on transit. It is an opportunity to put down ideas in practice as they come at any time and encourages more practice; and I gain more skills on programming using the virtual lab. I prefer the virtual lab environment to the traditional lab because in virtual lab I am at ease unlike the tension attached to the normal traditional lab and in virtual lab environment I express myself better. I recommend improvement on the network quality.

Speaker: Student2

Transcript

The virtual lab was easy to access, however there was network problem. The virtual lab was easy and friendly to use. It is good and it will help students to practice program coding more. It is an opportunity to practice program coding and is a welcome development. I preferred and recommend the virtual lab because it can be access anywhere anytime compare to the traditional lab where every student has to come to the lab.

Speaker: Student3

---

Transcript

The virtual lab was quite easy to access by typing in my login details then instantly I was able to access the VPL environment. The virtual lab is very friendly but I will also like to add that there may be a few limitations that I notice like not having the full compiler as on desktop. It is good for testing programs on the move, that is, I could have an idea that comes to mind I can just type (write the code) and test it, I can do this any time as long as I have Internet access. Using the virtual lab will improve my programming skills very well. I definitely preferred the VPL because of easy accessibility, and issue of having hardware (computers in a traditional lab) is a problem, while with VPL either with a phone or any capable device I can have access to a full programming compiler (environment) that I can find my programs. Cost-wise the VPL is very cost-effective because we will not have individual system to serve individual students; students can bring their systems not necessarily computer systems but their tablets or cell phones. I will really urge the University and the department to take this very seriously to go beyond just one programming language (i.e. it should not be limited to only Java programming language) to cover all the programming languages they are teaching in the computer science and that will be the major advantage.

---

Speaker: Student4

---

Transcript

---

Accessing the virtual lab for my Java programming activities was very easy because connecting to the virtual lab was achieved even with my mobile device. What I need is only Internet connection. Using the virtual lab was amazingly easy to use; at the beginning I thought it would be difficult to us. It is quite user-friendly and nice for program coding. The virtual lab experience was a wonderful one that I wish to use the virtual lab for all my programming courses in the department. Using the virtual lab for our exercises open my eyes to a new way of practicing programming and the instant feedback from the lecturer help me to correct my mistakes. Obviously the use of the virtual lab promote my Java programming skills. The virtual programming lab is far far better than our computer lab because not all students will get a computer in our lab to use at the same time but virtual lab can be access by many students at the same time. I will like the department to make sure all our lecturers use the virtual programming lab to teach all our courses. And the university should help the department to achieve this.

Speaker: Student5

I was able to access the virtual lab easily each time I want to use it to do my exercises or practice program coding. Using the virtual lab was easy for me to write programs and test them. The experience was a nice one. Each time I use the virtual lab, I feel as if the lab is on my laptop not being remote. The virtual lab is quite valuable for learning programming as students. It is a good technology for practicing Java programming because students can access it any time they want to do program coding as they wish. Using the virtual lab enable me to practice a lot of things on my own apart from the exercises given; and this really improved my programming skills. If we can use the virtual lab throughout to our final year, I am very sure all of us will be gurus in programming because our lecturers will find it easy to advice and guide us in the virtual lab. Use of the virtual lab is a good development for us students because we don't need to assemble ourselves in a computer lab with few computers that cannot even go round all students. Using the virtual lab will also save cost for the university in buying expensive computers to equip labs. It was very clear that using the virtual lab for our practical classes, we were able to gets our lecturer attention more, so I recommend the adoption of this important concept.

Speaker: Student6

The virtual programming lab was accessible all the time and anywhere that a choose to use it to practice programming. Using the virtual lab is as easy as using Facebook. There was no difference writing and running programs inside the virtual lab and doing same in our usual computer lab. The virtual lab is very interesting because I can use it to learn programming on my own. Using the virtual lab encourage students to spend more time practicing programming at their leisure time. Since more time is spend practicing programming in the virtual lab, more skills are also acquired at the end by students; and this make us better future programmers. The virtual lab is good for our large classes because we students can work independently in the virtual lab without queuing for computers to use. I prayed that may the department allow us to continue to use this virtual programming lab for all our programming courses so that we can have more time for hands-on programming practice.

---

2: Text Extracts of Students Interview Transcription Inside Nvivo

## Appendix E: Snapshot of Lecturer Interview Transcription from Nvivo and Text Extracts

The screenshot displays the Nvivo software interface. The top menu bar includes options like File, Edit, Create, Data, Analyze, Query, Explore, Layout, View, Window, and Help. The main window is titled 'Virtual Lab' and shows a project structure on the left with categories like SOURCES, NODES, CLASSIFICATIONS, and COLLECTIONS. The central area displays a transcription of a lecturer interview. The transcript is organized into a table with columns for Start Time, End Time, Transcript, and Speaker. The transcript content includes several paragraphs discussing the accessibility and usefulness of a virtual lab environment for teaching programming.

Start Time	End Time	Transcript	Speaker
00:00:01.1	00:04:57.8	<p><b>What can you say about the accessibility of the virtual lab?</b>                      The virtual lab is accessible anytime anywhere as long as you have login details; with the virtual lab I was able to set Java programming assignments for students and check their submissions using my iPad. <b>How easy was using virtual lab since this is your first time to use it for teaching?</b>                      Using the virtual lab was surprisingly very simple. I was able to view and comments on students' lab activities online even at home. <b>Did the virtual programming lab environment enable you to manage your practical classes?</b>                      The virtual programming lab environment is an ideal lab for contemporary program coding teaching and learning because assisting learners in the virtual lab environment is much easier for a large class compare to normal lab. I was able to attend to each student in the VPL environment. Also the virtual lab activities encourage introverts' students to talk online. Scaffolding students' lab activities in the virtual lab was lovely because they received instant feedbacks. <b>With your experience now can you consider the virtual lab useful?</b> I must confess that the virtual lab experience has shaped my pedagogical thoughts and approach to teaching programming courses. The virtual lab is very useful especially for large classes and for teaching computer age students who like self-pace and independent practice. <b>Do you have any comment or recommendation about the virtual lab?</b>                      The virtual lab is the way forward for our department in teaching all programming courses because we cannot be able to conduct all programming practicals in our small physical computer lab that have few systems.                      I will recommend the full usage of the virtual programming lab to my head of department (HOD) for implementation. The virtual lab could also be use by other science department for conducting their practicals.                      The virtual programming lab is an opportunity to explore delivering computer science as a distance-learning program me in the department. Using virtual lab for our courses will definitely improve our students' practical programming skills.</p>	Lecturer

1: Snapshot of Lecturer Interview Transcription Inside Nvivo

**What can you say about the accessibility of the virtual lab?**

The virtual lab is accessible anytime anywhere as long as you have login details; with the virtual lab I was able to set Java programming assignments for students and check their submissions using my iPad. **How easy was using virtual lab since this is your first time to use it for teaching?**

Using the virtual lab was surprisingly very simple. I was able to view and comments on students' lab activities online even at home. **Did the virtual lab environment enable you to manage your practical classes?**

The virtual lab environment is an ideal lab for contemporary program coding teaching and learning because assisting learners in the virtual lab environment is much easier for a large class compare to normal lab. I was able to attend to each student in the VPL environment. Also the virtual lab activities encourage introverts' students to talk online. Scaffolding students' lab activities in the virtual lab was lovely because they received instant feedbacks. **With your experience now can you consider the virtual lab an opportunity to enhance learners' programming skills?** I must confess that the virtual lab experience has shaped my pedagogical thoughts and approach to teaching programming courses. The virtual lab is very useful especially for large classes and for teaching computer age students who like self-pace and independent practice.

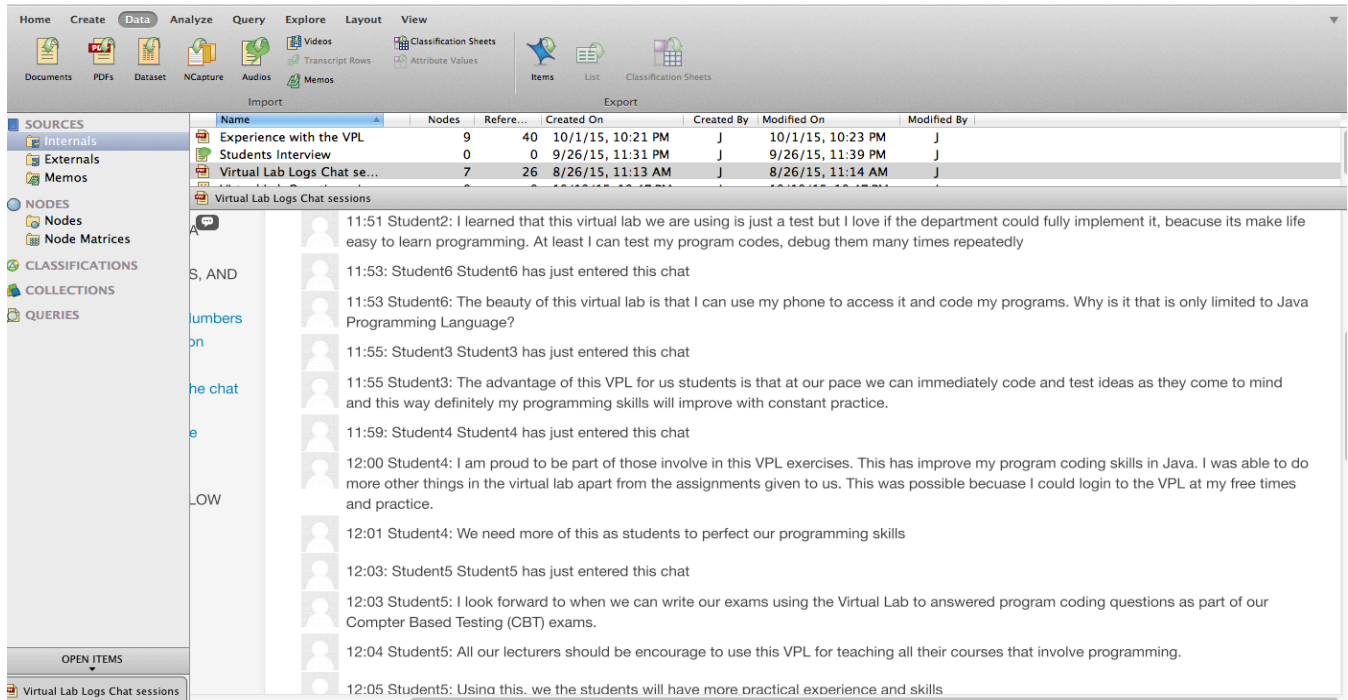
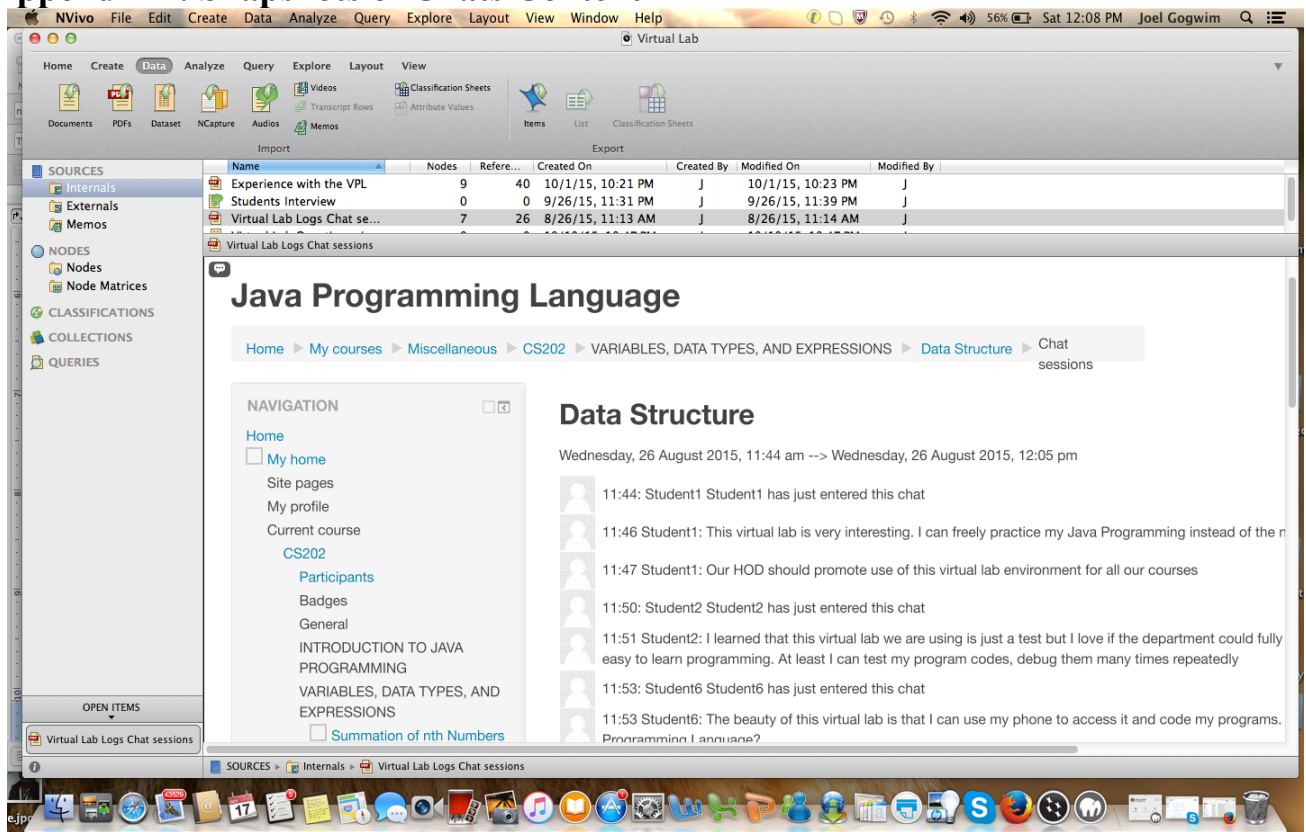
**Do you have any comment or recommendation about the virtual lab?**

The virtual lab is the way forward for our department in teaching all programming courses because we cannot be able to conduct all programming practicals in our small physical computer lab that have few systems.

I will recommend the full usage of the virtual programming lab to my head of department (HOD) for implementation. The virtual lab could also be use by other science department for conducting their practicals.

The virtual programming lab is an opportunity to explore delivering computer science as a distance-learning program me in the department. Using virtual lab for our courses will definitely enhance our students' practical programming skills.

# Appendix F: Snapshots of Chats Content



Snapshots of chats Content

# Appendix G: Snapshots of Forum Content

Home Create Data Analyze Query Explore Layout View

**Import**

**Export**

	Name	Nodes	Refere...	Created On	Created By	Modified On	Modified By
<b>SOURCES</b>							
Internals	Experience with the VPL	9	40	10/1/15, 10:21 PM	J	10/1/15, 10:23 PM	J
Externals	Students Interview	0	0	9/26/15, 11:31 PM	J	9/26/15, 11:39 PM	J
Memos	Virtual Lab Logs Chat se...	7	26	8/26/15, 11:13 AM	J	8/26/15, 11:14 AM	J
	Virtual Lab Questionnair...	0	0	10/10/15, 10:47 PM	J	10/10/15, 10:47 PM	J
<b>NODES</b>	Experience with the VPL						
Nodes							
Node Matrices							
<b>CLASSIFICATIONS</b>							
<b>COLLECTIONS</b>							
<b>QUERIES</b>							
Queries							
Results							

You are logged in as [Joel Gogwim](#) (Log out)

## Learning Language

[Home](#) > [CS202](#) > [METHODS](#) > [Virtual Lab Experience](#) > [My experience with the VPL](#)

Virtual Lab Experience

Display replies in nested form

Move this discussion to ...

**My experience with the VPL**

by [Student3 Student3](#) - Monday, 24 August 2015, 11:05 pm

The virtual programming lab is a wonderful experience for me; I could imagine running programs online using my PIPO Android tablet. I am convinced that by using the VPL, it is possible to teach Computer Science courses fully online using eLearning for distance education.

Doing the activities in the Virtual Lab was more interesting than the usual physical lab method that is full of distractions and limited time access to the lab for one to complete his assignments and test them properly before submission.

I recommend that the university should encourage the use of the VPL for teaching programming courses in the department.

**OPEN ITEMS**

- [Programming Skills Acqui...](#)
- [Recommendation for Virt...](#)
- [Student Engagement](#)
- [Virtual Lab Accessibility](#)
- [Experience with the VPL](#)

Node Matrices

CLASSIFICATIONS

COLLECTIONS

QUERIES

Queries

Results

---

OPEN ITEMS

- Programming Skills Acqui...
- Recommendation for Virt...
- Student Engagement
- Virtual Lab Accessibility
- Experience with the VPL

**Re: My experience with the VPL**  
by [Student4 Student4](#) - Monday, 24 August 2015, 11:07 am

Working in the virtual lab environment has no tension and fear like the traditional computer lab. At anytime I can do my exercises independent of other students and I can decide to spend more time practicing coding on my own.

This development should be encourage and put to use, no going back. My experience with the VPL was worthwhile and I like it. My friend who did not participated in this VPL exercises envy the six of us having access to the VPL environment.

[Show parent](#) | [Edit](#) | [Split](#) | [Delete](#) | [Reply](#)

**Re: My experience with the VPL**  
by [Student5 Student5](#) - Monday, 24 August 2015, 11:09 am

My experience with the virtual lab was encouraging for me because I was able to practice repeatedly and gain more confident as programming students. I will appreciate if our student programming club could adopt this VPL as a practice environment that hopefully will train us to be good programmers.

[Show parent](#) | [Edit](#) | [Split](#) | [Delete](#) | [Reply](#)

**Re: My experience with the VPL**  
by [Student1 Student1](#) - Tuesday, 25 August 2015, 11:12 am

Node Matrices

CLASSIFICATIONS

COLLECTIONS

QUERIES

Queries

Results

---

OPEN ITEMS

- Programming Skills Acqui...
- Recommendation for Virt...
- Student Engagement
- Virtual Lab Accessibility

**Re: My experience with the VPL**  
by [Student4 Student4](#) - Monday, 24 August 2015, 11:07 am

Working in the virtual lab environment has no tension and fear like the traditional computer lab. At anytime I can do my exercises independent of other students and I can decide to spend more time practicing coding on my own.

This development should be encourage and put to use, no going back. My experience with the VPL was worthwhile and I like it. My friend who did not participated in this VPL exercises envy the six of us having access to the VPL environment.

[Show parent](#) | [Edit](#) | [Split](#) | [Delete](#) | [Reply](#)

**Re: My experience with the VPL**  
by [Student5 Student5](#) - Monday, 24 August 2015, 11:09 am

My experience with the virtual lab was encouraging for me because I was able to practice repeatedly and gain more confident as programming students. I will appreciate if our student programming club could adopt this VPL as a practice environment that hopefully will train us to be good programmers.

[Show parent](#) | [Edit](#) | [Split](#) | [Delete](#) | [Reply](#)

**Re: My experience with the VPL**  
by [Student1 Student1](#) - Tuesday, 25 August 2015, 11:12 am

The virtual lab is a friendly practicals environment that enable self-practice at any time and place as long as there is connection. The virtual lab activities allow us as students to share ideas via chats and forum like this discussing the VPL experience.

[Show parent](#) | [Edit](#) | [Split](#) | [Delete](#) | [Reply](#)

**Re: My experience with the VPL**  
by [Student6 Student6](#) - Tuesday, 25 August 2015, 11:11 am

Working in the virtual lab is the best for any programming practice or learning. However the compilers should include other languages like PHP, C++, etc so that we can continue to use the VPL for all our programming lab activities. Even on transit I was able to access the Virtual Lab.

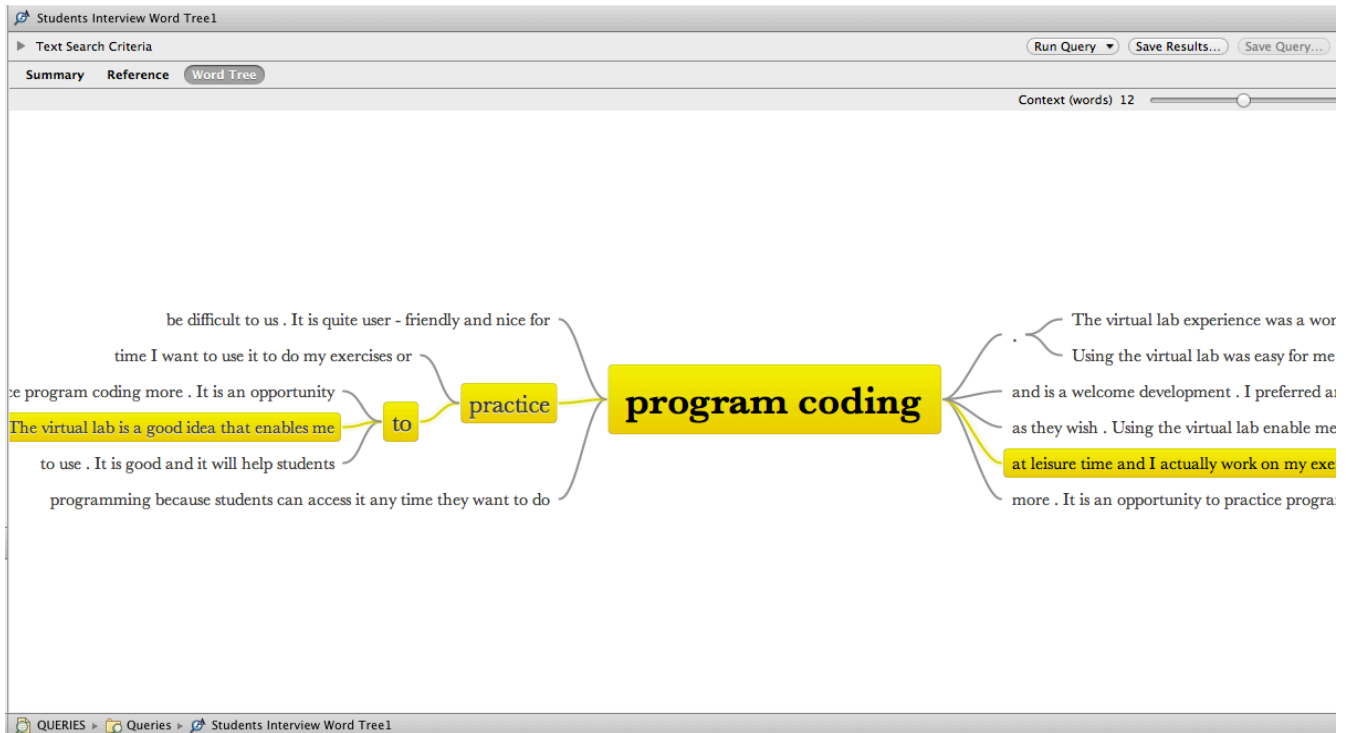
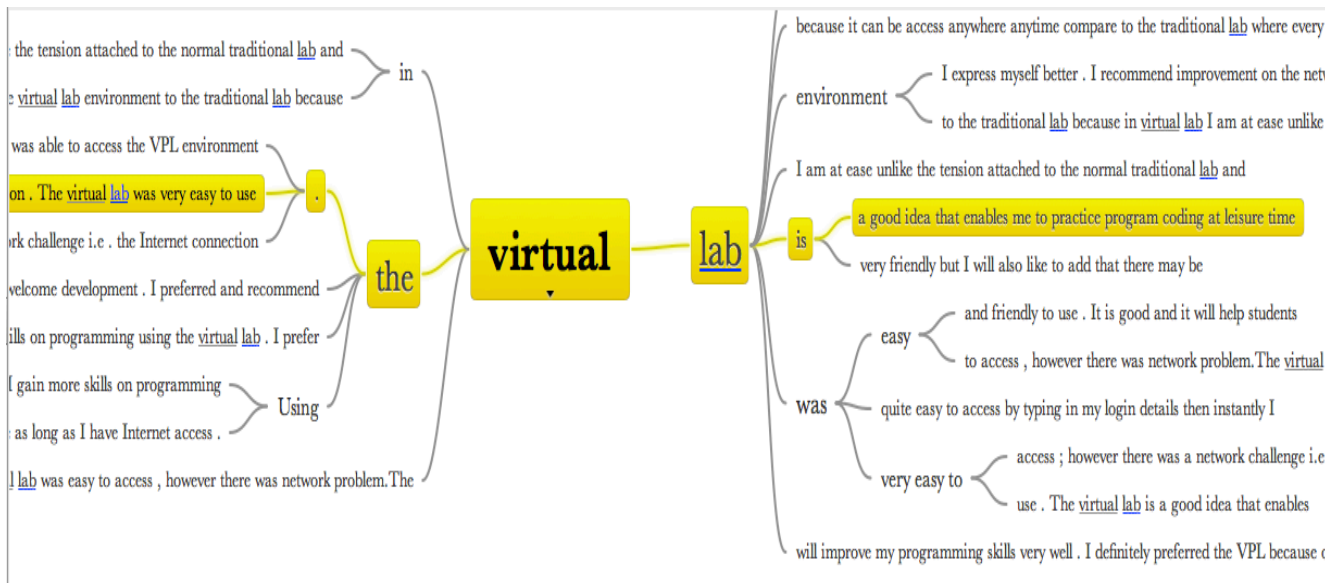
[Show parent](#) | [Edit](#) | [Split](#) | [Delete](#) | [Reply](#)

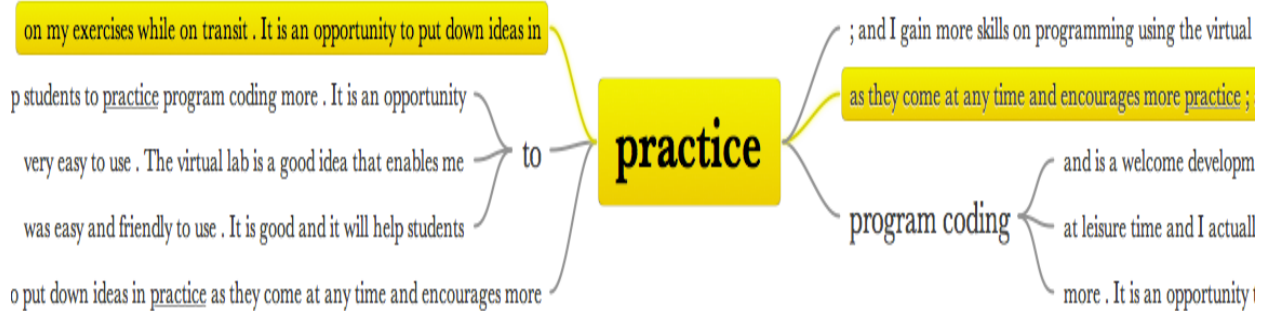
**Re: My experience with the VPL**  
by [Student2 Student2](#) - Monday, 24 August 2015, 11:04 pm

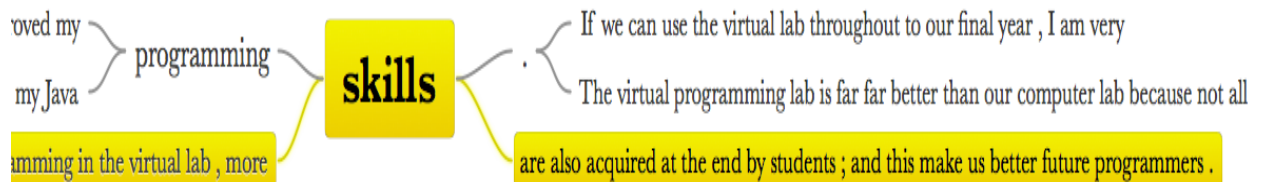
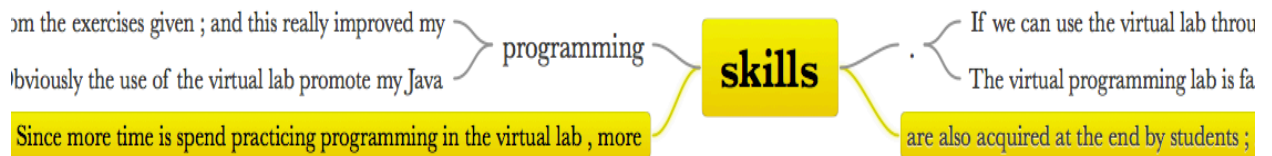
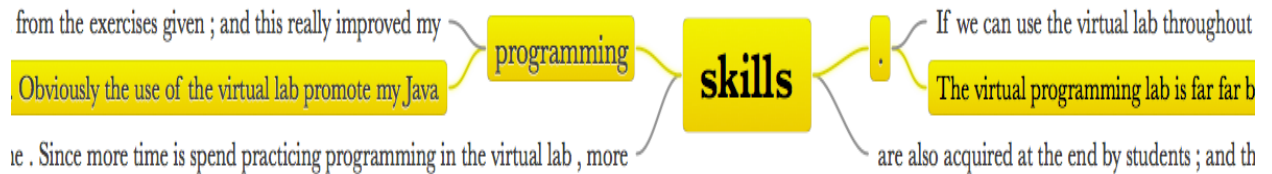
My experience with the virtual lab environment was quite engaging. It is the best thing that can happen to any computer science student. I wish all our mates experience this VPL environment, it is quite rewarding to practice program coding and debug errors online seamlessly. This is a great ICT tool that can be use for large classes where attending to all students just in one class at a time is not possible. Is an opportunity for shy students to express themselves too

Snapshots of NCapture Forum Log Data Imported into Nvivo

## Appendix H: Word Trees of Students' Interview Transcription Highlighting Relevant Statements

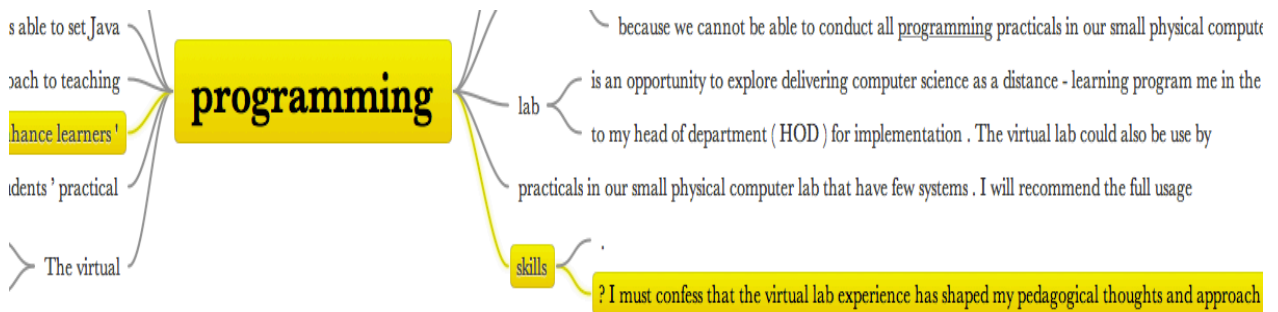
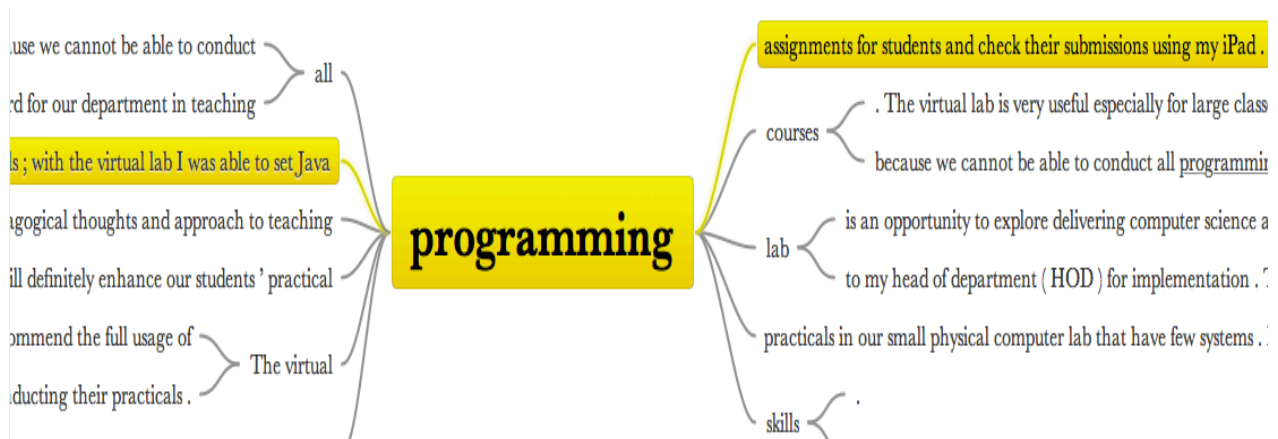
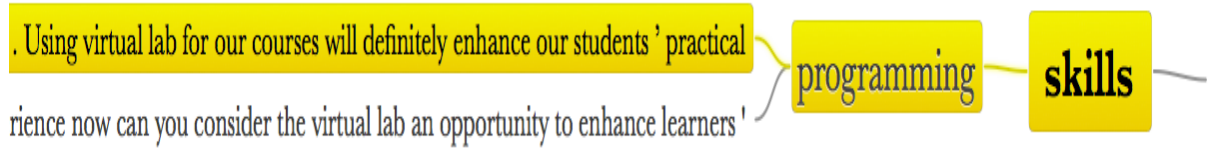


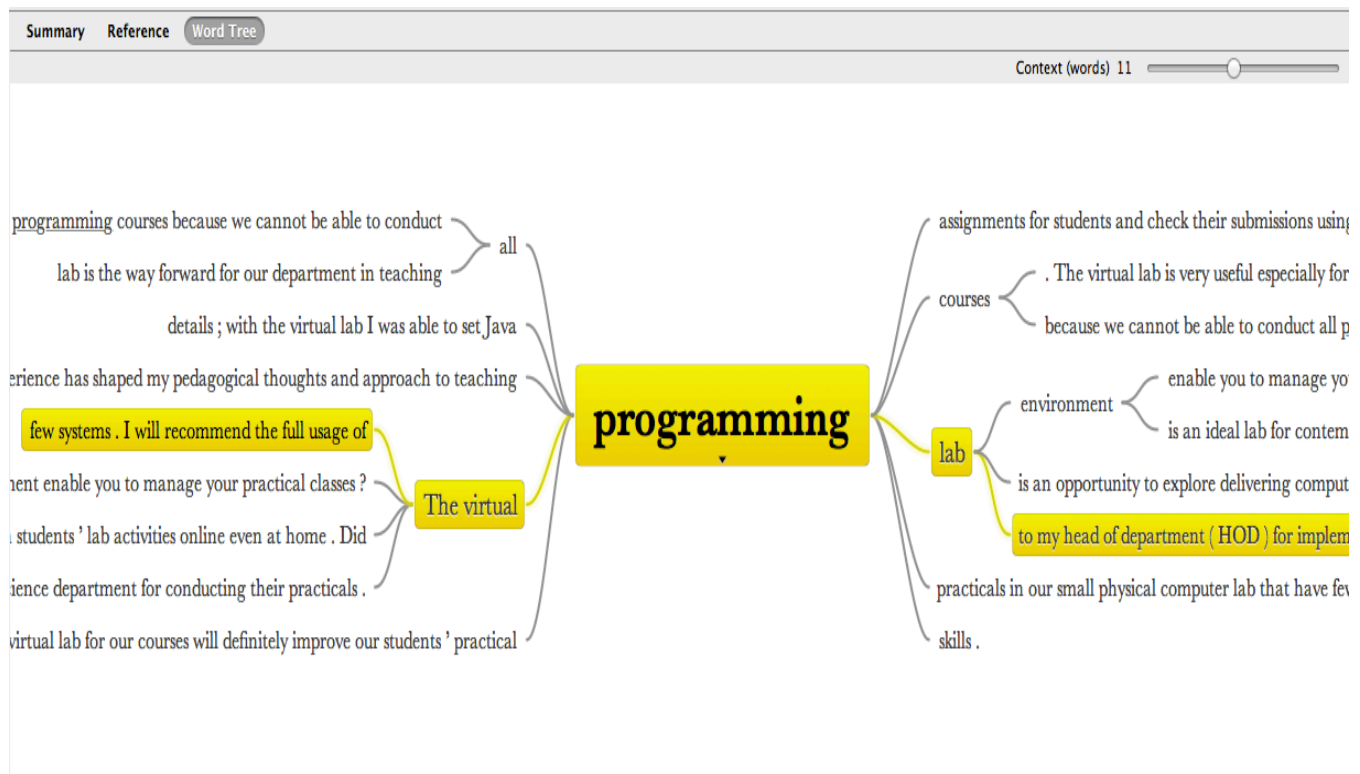




Word Trees of Students' Interview Transcription highlighting relevant statements made by the students during the interview.

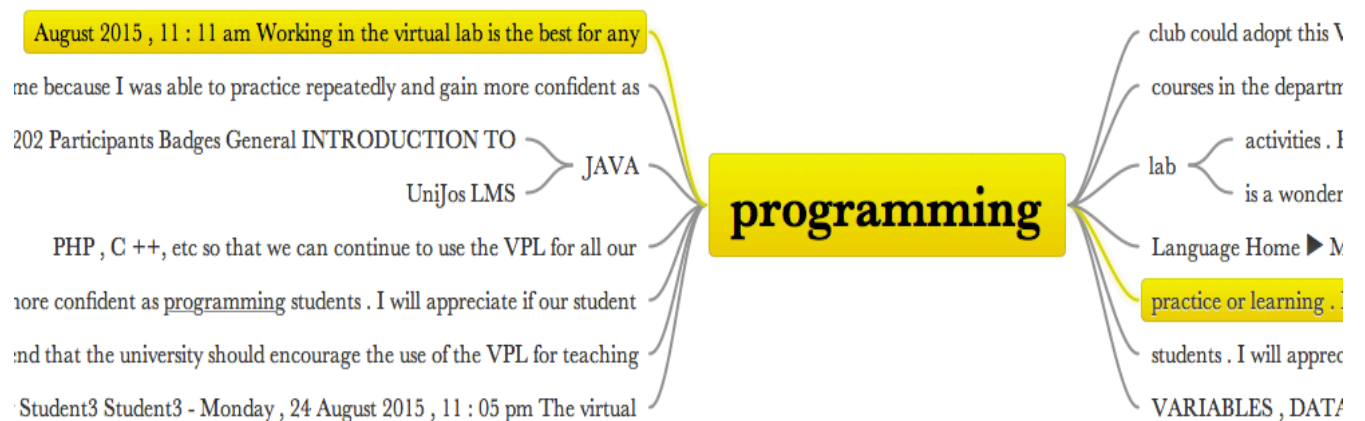
## Appendix I: Word Trees of Lecturer's Interview Transcription Highlighting Relevant Statements

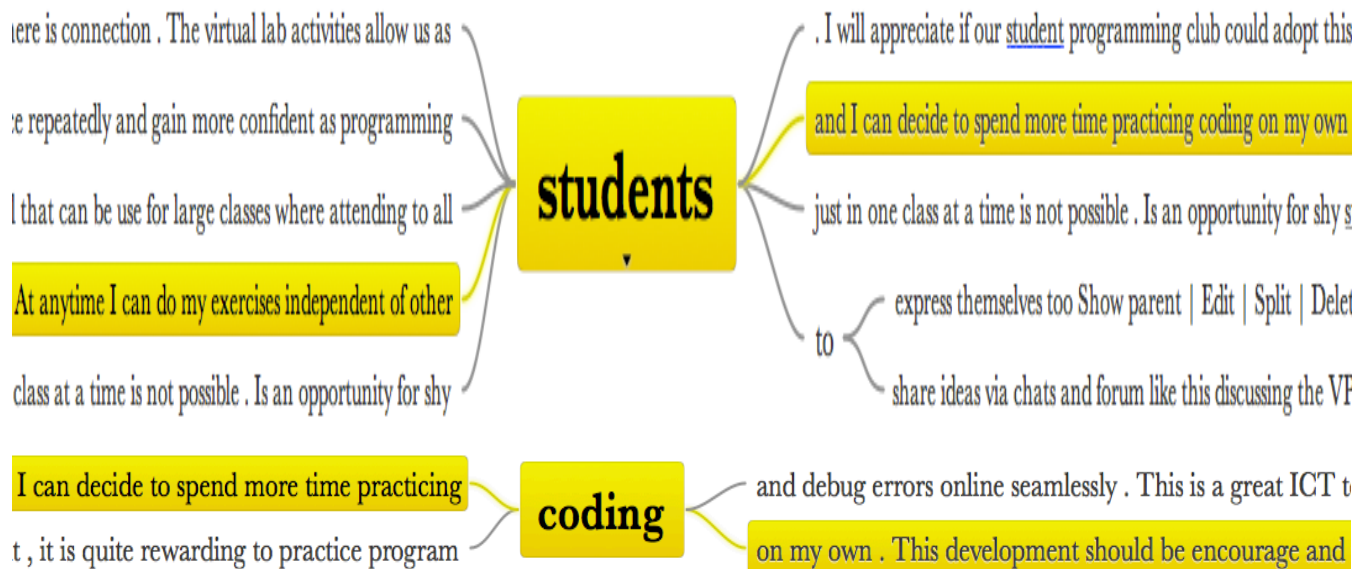
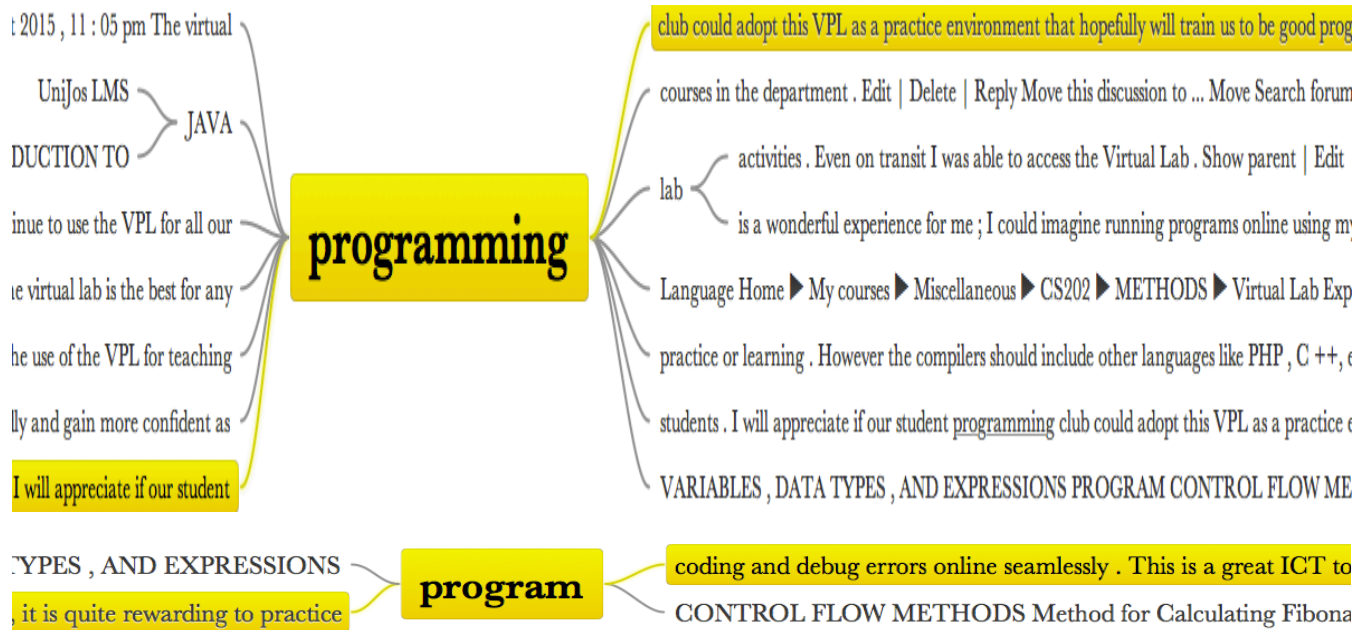




Word Trees of Lecturer Interview Transcription highlighting the lecturer's statements during the interview.

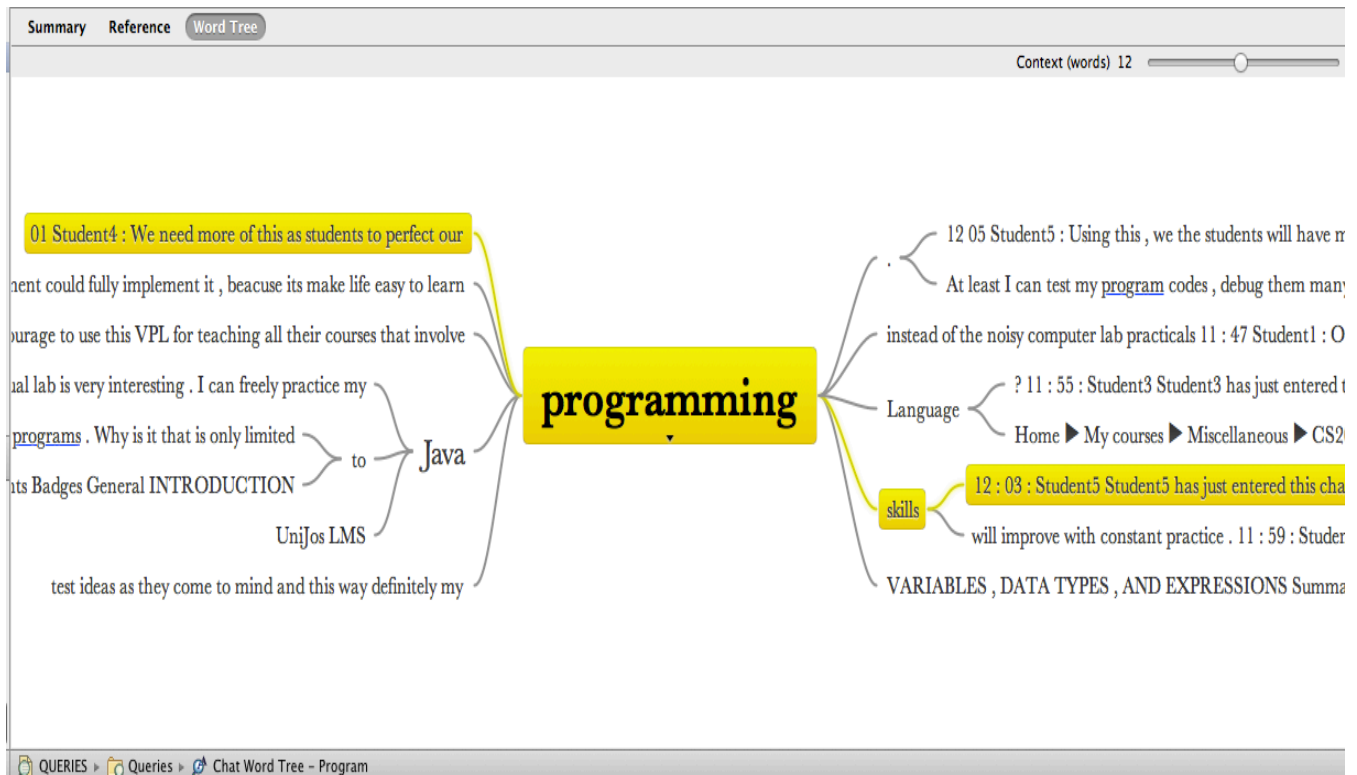
## Appendix J: Word Trees of Forum Content Highlighting Relevant Statements

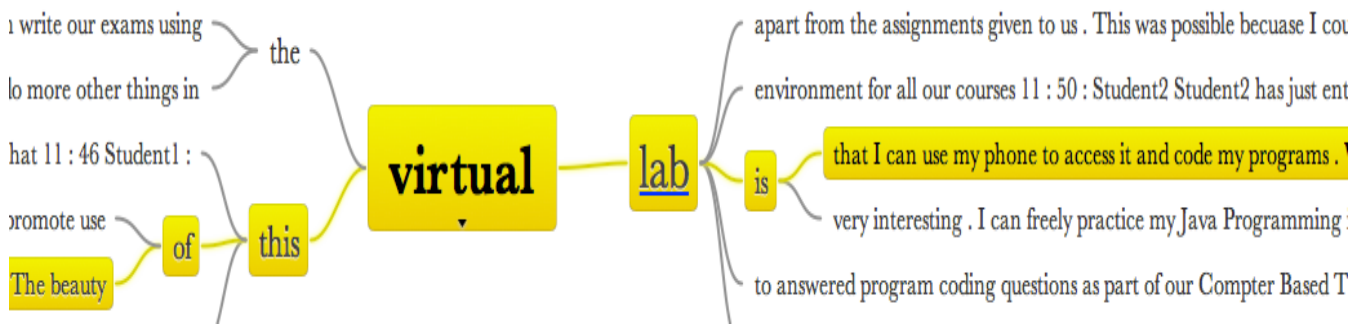
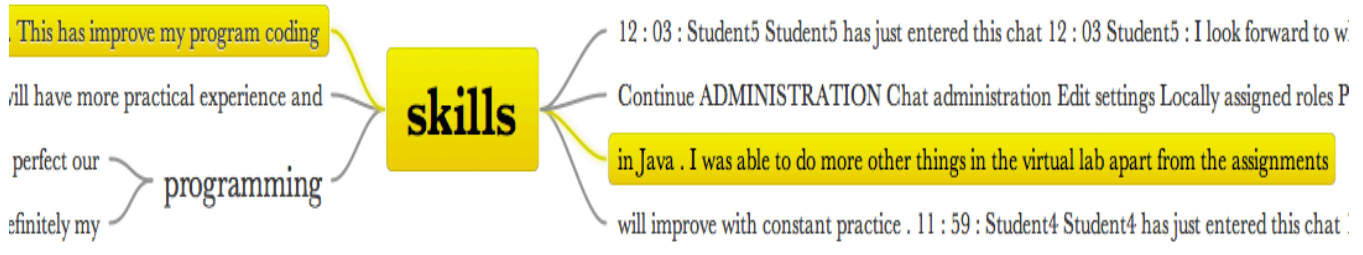
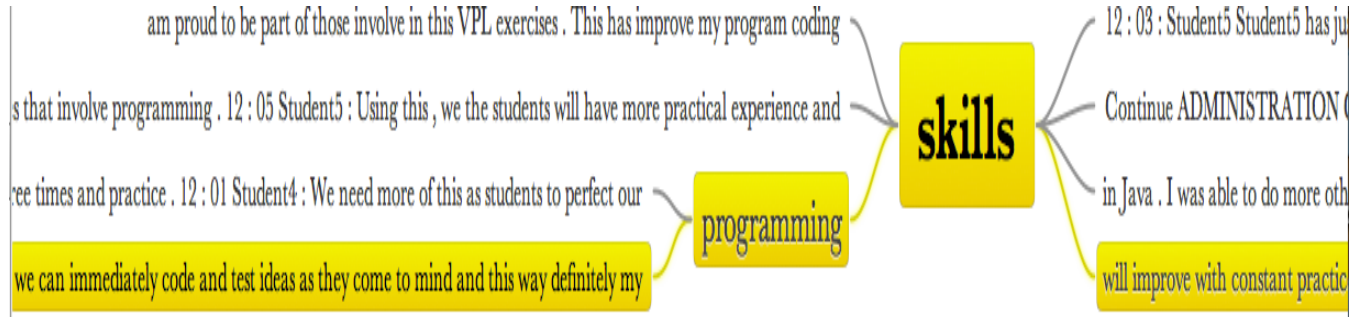
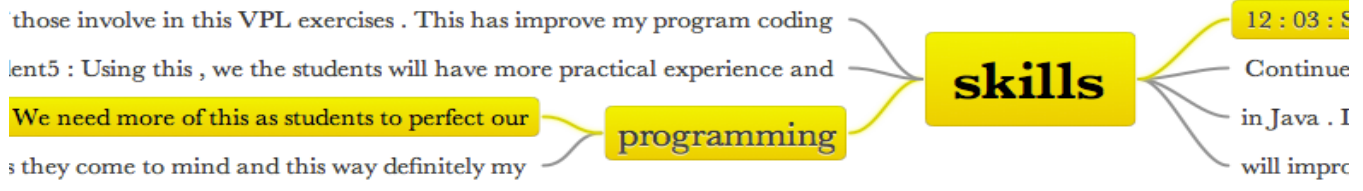


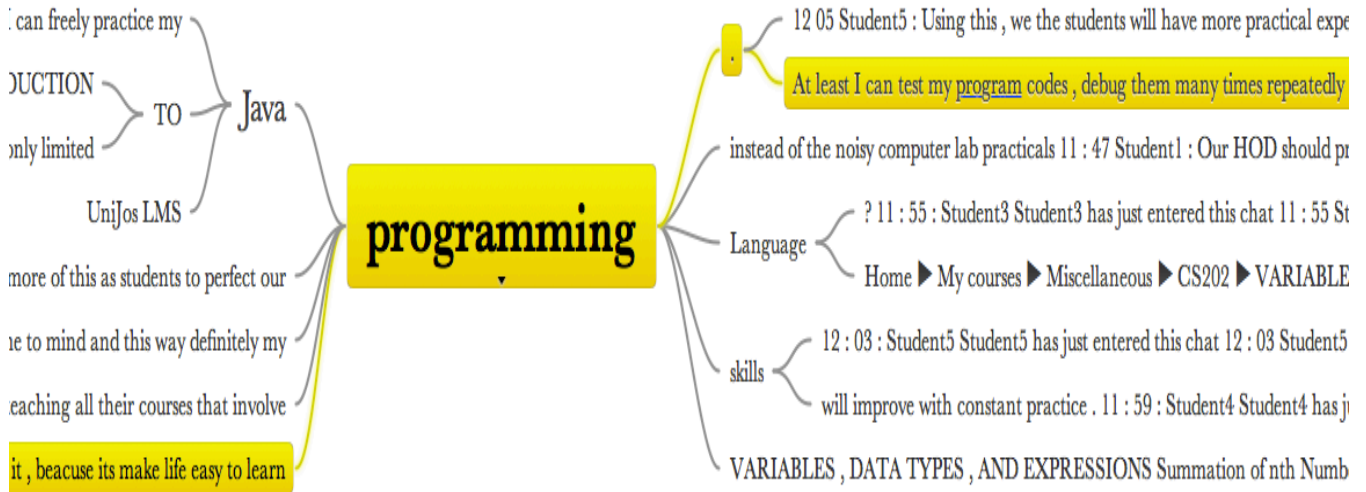


Word Trees of Virtual Lab Activities Forum Logs

## Appendix K: Word Trees of Chats Content Highlighting Relevant Statements

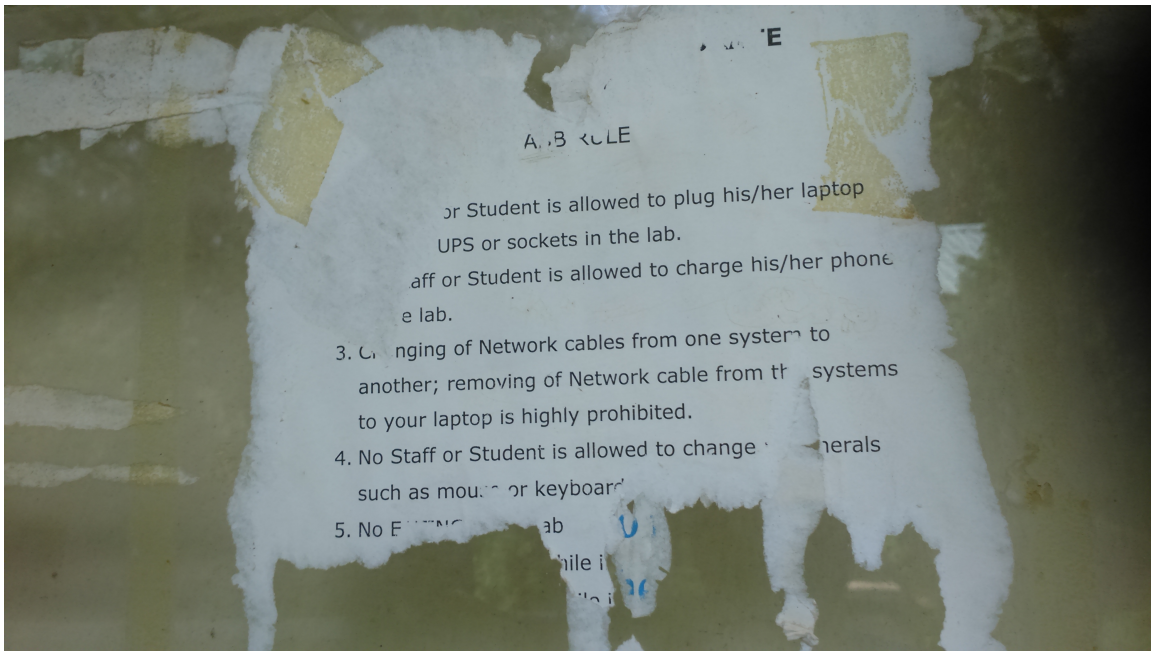






Word Trees of Virtual Lab Activities Chats Logs

## Appendix L: Computer Lab Guidelines



The Computer Lab Rules and Guidelines

## Appendix M: Screenshots of Assigned Tasks

The screenshot displays the UniJos LMS interface for the 'Java Programming Language' course. The browser address bar shows 'elearn.unijos.edu.ng/course/view.php?id=4'. The page title is 'UniJos LMS' and the course title is 'Java Programming Language'. The breadcrumb trail is 'Home > My courses > Miscellaneous > CS202'. The left sidebar contains two main sections: 'NAVIGATION' and 'ADMINISTRATION'. The 'NAVIGATION' section includes links for 'Home', 'My home', 'Site pages', 'My profile', and 'Current course' (CS202). The 'ADMINISTRATION' section includes links for 'Course administration', 'Turn editing on', 'Edit settings', 'Users', 'Unenrol me from CS202', 'Filters', 'Reports', 'Grades', and 'Badges'. The main content area features a course description: 'This course introduces computer programming using the JAVA programming language with object-oriented programming principles. Emphasis is placed on event-driven programming methods, including creating and manipulating objects, classes, and using object-oriented tools such as the Applets, etc'. Below the description are three assigned tasks, each with a computer icon: 'Hello Program', 'Write a program that will search for a word in a string', and 'Write a program in Java that print summation of nth numbers'. The 'Data Structure' section lists six topics: '1. Identifier rules', '2. Naming variables, constants (final) and references', '3. Primitive data types', '4. Arithmetic Operators', '5. Assignment Operators', and '6. Relational and Logical Operators'. Below this list are two more assigned tasks: 'Write a program that will implement stack' and 'Data Structure' (two instances).

UniJos LMS

### Java Programming Language

Home > My courses > Miscellaneous > CS202

**NAVIGATION**

- Home
  - My home
  - Site pages
  - My profile
  - Current course
    - CS202**
      - Participants
      - Badges
      - General
      - Java Strings
      - Data Structure
      - Program Control Flow
      - Methods
      - Java Applets

This course introduces computer programming using the JAVA programming language with object-oriented programming principles. Emphasis is placed on event-driven programming methods, including creating and manipulating objects, classes, and using object-oriented tools such as the Applets, etc

Hello Program

---

### Java Strings

Write a program that will search for a word in a string

---

### Data Structure

This topic will cover the following:

1. Identifier rules
2. Naming variables, constants (final) and references
3. Primitive data types
4. Arithmetic Operators
5. Assignment Operators
6. Relational and Logical Operators

Write a program in Java that print summation of nth numbers

Write a program that will implement stack

Data Structure

Data Structure

Site administration

## Methods

This topic covered the following sections:

1. Java API and Package/Library [methods](#)
2. User-defined [methods](#)
3. Scope and duration
4. Local and Field variables
5. Pass-by-value, Pass-by-reference
6. Recursion
7. Overloading



Write a Java program that use method for calculating Fibonacci series



Write a Java program that use method for calculating Factorial of a number



Create Shapes with Applets



Virtual Lab Experience



Methods

---

### 7. Overloading



Write a Java program that use method for calculating Fibonacci series



Write a Java program that use method for calculating Factorial of a number



Create Shapes with Applets



Virtual Lab Experience



Methods

---

## Java Applets

Applets



Write a simple Java program that create different shapes using Applet



Java Applets



Java Applets

---

## Screenshots of assigned tasks

Key: Virtual Lab activity Forum Chats