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Addressing the Challenges of Computer Science Learning Through Curriculum Redesign and Practical Skills Acquisition

ONWUDEBELU UGOCHUKWU & IREM PATRICK
Federal University Ndufu-Alike Ikwo, Abakaliki, Nigeria

ABSTRACT Exploration and/or experimentation are a necessity for every discipline, and are at the heart of innovation in all disciplines. Laboratories naturally provide purposeful activities that direct students' exploration. The main objective of Computer Science laboratory is to allow students and staff develops their skills in the use of software and its applications as well as helping in scientific investigations. However, the case is not true of most CS Lab in some of our universities. Therefore, it is of most utmost importance, that CS lab be used for the purpose for which it was built and in instance where they are non-existence, it is pertinent that, it should be established since most lab exercises include activities that help in skills acquisition. This necessitated the writing of this paper. After, surveying the curricula of some selected universities, we discovered that there were virtually no courses dedicated purely to practical skills in CS. This led to the introduction of one in our university; we also discuss the practical teaching of Computer Science in the lab and its reflection in the curriculum. Note that hands-on laboratory experience is critical to the understanding of theoretical concepts studied in the theory courses in Computer Science.

Keywords: Computer Science, laboratory, curriculum, practical skills, NUC, Information Technology

Introduction

Exploration and experimentation are at the heart of advancement in all disciplines. The report from the ACM/IEEE-CS Joint Curriculum Task Force stipulates: "Most courses in a computer science program must include a laboratory component that requires students to develop their technical skills and acquire an understanding of effective professional practice" (Chang, 2001). This report reinforces the importance of including laboratory experiences to the learning process, especially at the first year of every student's academic life. Generally, to many students, a 'lab' means manipulating equipment but not manipulating ideas (Lunetta, 1998). Nevertheless, the laboratory skill is needful to beginner in Computer Science (CS) discipline, as students will gain communication, project management, teamwork, and leadership skills critical to success in today's rapidly changing, technology-driven world (Casey, 2015). With such skills acquired by students at their early life, it will act as a catalyst to solutions to challenges faced by future employers at their organizations.

The laboratory journeying holds significant promise for being able to support conceptual learning when facilitating and conducive conditions are put in place for students. Within the science curriculum, the role of student's laboratory work has shifted dramatically over the past century. There have been a broad variety of educational purposes ascribed to laboratory instruction and historically little consensus about how it can best support learning (Lazarowitz & Tamir, 1994, Lunetta, 1998) although the situation seems to be improving (Hofstein & Lunetta, 2004; Millar, 2004). Laboratory experiences are relevant for most CS courses—from literacy and language courses through theory courses. While not claiming that all CS courses should be completely laboratory-based, we do believe that most courses can benefit from the use of some well designed laboratory components. Laboratories can be used for both exploration and the illumination of difficult concepts. Experimentation should be encouraged at all levels as it is an important means for obtaining knowledge (Knox et al, 1996). Laboratories typically provide focused activities that direct students' exploration, for instance, a World Wide Web (WWW) exploration of a topic of interest to the individual student, with detailed descriptions of his/her exploratory activities. Another explorative ability will be the ability to read and understand programs written by others, which is a very important skill needed by programmers.

Technology especially computer system has become ubiquitous as it is been used in the banks, hospital, factories, shopping centers etc and universities in their part, are trying to meet the needs of an increasingly diverse population. The increasingly availability of information technologies (IT) in schools allow students to learn about current scientific research and engage in inquiry at the frontiers of scientific knowledge (Bell, 2004). As system and software prices have dropped drastically, and home computers become more powerful, it is now possible that more students will have the required resources in their homes to support all of the activities typically performed in the lab (Margush, 2002).

The Lack of General Practical for CS in BMAS Documents

National Universities Commission (NUC) is a dynamic regulatory body that is saddle with the responsibility of acting as a catalyst for positive change and innovation for the delivery of quality university education in Nigeria. After more than a decade of using the Minimum Academic Standard (MAS) documents as a major instrument of accreditation, the Commission in 2001 initiated a process to revise the documents based on the fact that the frontier of knowledge in all academic disciplines had been advancing with new information generated as a result of research and the impact of ICT on teaching and learning. Other compelling reasons included the need to update the standard and relevance of university education in the country as well as to integrate entrepreneurial studies and peace and conflict studies as essential new platforms that will guarantee all graduates from Nigerian universities the knowledge of appropriate skills, competences and dispositions that will make them globally competitive and capable of contributing meaningfully to Nigeria's socio-economic development. The content-based MAS documents were rather prescriptive, a decision was taken to develop outcome-based benchmark statements for all the programmes in line with contemporary global practice (NUC, 2007). Later, it was discovered that the bench mark-style statements were too sketchy to meaningfully guide the development of curricula and were also inadequate for the purpose of accreditation. Given this scenario, the Commission therefore considered the merger of the Benchmark Style Statements and the revised Minimum Academic standards into new documents to be called Benchmark Minimum Academic Standards (BMAS).

Bringing Technology into the Classroom

As mentioned above to many students, a 'lab' means manipulating equipment (tools) but not manipulating ideas. Students will always be faced with the issues of data collection, modelling, and analysis in one course/discipline or another. And therefore will need a tool like spreadsheet (excel) with which data collection, modelling, and analysis in a diversity of settings can be accomplished. The use of a spreadsheet-based model that simulates world population growth or spread of disease such as Ebola is a good example. Students can also explore the effects of changing the inputs to the model thus learning about the power and deficiencies of computer modelling. Similarly, other tools such as PowerPoint, access, word processor applications etc can be deployed and exploited in different courses. We should encourage the use of such tools in our courses thus bringing technology into the classroom.

The laboratory is a place where students and teachers interact to acquire innovative skills, to perform experiments as well as to broaden their experiences. Although from the students' perspective is a place for manipulations of equipment, nonetheless, the equipment do not all have to be in the same room (Knox et al), however, one of the exciting thing about CS laboratories is that they can extend beyond physical boundaries. Advances in technology and the readily available hardware and software needed to decentralize the computer laboratory to make it feasible to explore distance learning implementations of the closed laboratory model (Margush, 2002). As the world is becoming more of a lab and non-scientists become involved in the shaping of scientific questions for example through the activities of NGOs and citizen science activities (Latour, 2003), people have opportunities to interact and learn more than ever before.

Methodology

We survey NUC Benchmark Minimum Academic Standards (BMAS) for Science undergraduate programme in Nigeria with a particular interest with first year courses which has to do with practical courses in various science departments and came up with Table 1 while Table 2 is the summary of the NUC BMAS minimum laboratory equipment required for teaching in a Computer Science department.

Table 1: Year 1 (100 Level) Practical Courses for Various Departments

Department	***Course Code***	***Course Title***	***Units***
Biochemistry, Biotechnology, Chemistry, Industrial Chemistry, Meteorology, Physics,	BIO 107/108 CHM 107/108 PHY 107/108	General Biology Lab. I & II General Chemistry Lab. I & II General Physics Lab. I & II	2 2 2
Biology, Botany	PHY 105	General Physics Lab.	1
Brewing Science and Technology	PHY 112/122	General Physics Lab. I & II	2
Computer Science, Geology, Mathematics, Microbiology, Statistics, Zoology	Nil	Nil	Nil
Environmental Management and Toxicology	CHM 191/192	Practical Chemistry I & II	2
Applied Geophysics	CHM 107/108 PHY 107/108	General Chemistry Lab. I & II General Physics Lab. I & II	2 2
Science Laboratory Technology	ST/PE 107 ST/PE 108	General Physics Lab. I General Physics Lab. II	1 2

*Table 2**:** List of Important Equipment Required for Teaching in a CsS Department*

S/NO.	***Description***	***QTY. REQD***
Hardware Components		
1	CPU with minimum of 2 MB of main memory .	1
2.	Disk Drive	1
3.	Tape Drive	1
4.	Line Printer (300 LPM)	1
5.	VDU Terminals (Ideally there should be one terminal per every 5 students)	6
Software Components		
6.	COBOL, FORTRAN, BASIC, PASCAL, C Compilers, DOMS, Word Processing, Time Sharing Operating System,	
Hardware Laboratory		
7.	Logic Development System with necessary accessories	1
8.	Logic Analyser with Scope	4
9.	Micro Trainer Kits	6
10.	Digital Oscilloscopes	6

Discussion

Looking critically at Table 1, it can be seen that NUC BMAS says nothing concerning practical course in CS at the first year in the university. This ought not to be as computer system and technologies have permeated every fabric of our educational systems (i.e. every discipline makes used of computer system). Most disciplines have practical courses at the first and second semesters of their programme but the reverse is the case with CS. With such system in place, the lab work of most universities in CS would amounts to empty, virtual ritualistic procedures resulting in no practical being done. It is not enough having laboratory with equipments without any course title and course code attached to the programme—CS has no practical course title/ code as other courses, for instance in Table 1 we have BIO107/108, CHM107/108, PHY107/108 etc. There is a need for NUC to introduce CSC107/108 to ensure that students are taken to the CS laboratory for practical skill acquisition. Establishing CSC107/108 is very essential because this being the first year of the course, a good foundation laid in this year will make it easier for students to grasp advanced concepts in the years to come. The systematic completing of course material such as CSC107/108 fully connected to the conceptual understanding of the associated subject matter enables students to acquire some degree of practical skills. This form of confirmatory lab participation helps student to develop conceptual understanding as they engage in inquiry (CS courses). This being the first year of the course, a good foundation laid in this year will make it easier for students to grasp advanced concepts in the years to come. At the end, the students will be better positioned to face the outside world and become employable to the big companies. NUC needs to upgrade Table 2, for example the software needs to illustrate presence day reality, such as Windows Vista, Windows 7, Java versions, C#, Phython, etc. On the hardware part newer architectures should accommodate modern technologies: cloud computing services, web services, persistence models, distributed file systems/repositories (Google, Hadoop), multi-core, wireless and mobile.

As part of addressing the challenges of computer science learning through curriculum redesign and practical skills acquisition we introduce workbook (lab book). Workbook is one of the most helpful tools for students and we introduced a workbook as no lab book was present. One of the objectives of the workbook is for continuous assessment of the course. Students were expected to carry their workbook every time they come to the lab for CS practical. This workbook is mandatory for the completion of the laboratory course. It is a measure of the performance of the student in the laboratory for the entire duration of the course. Automatic feedbacks were given to students during the practical session as well as it were also made available to student after the completed assignment has been submitted. Students will benefit from eventually seeing a correct solution, so it is important to provide feedback once the assignment has been graded. Consequently, making the target audience (students) to acquire and gain laboratory experience.

Some institutions surveyed without any stand-alone practical course in Computer Science in their curricula include the following: University of Ibadan Oyo, Nnamdi Azikiwe University Awka, Federal University Lokoja, Federal University of Technology Minna, Rhema University Aba, Bells University of Technology Otta, Covenant University Ota, Crawford University Igbesa, Salem University Lokoja, Benue State University Makurdi etc.

FUNAI Laboratory Environment

Figure 1: FUNAI Laboratory Environment

The beginning level course in CS lab practical is CSC 107 entitled, *"Practical skills in Computer Science",*although CSC 101 entitled, *"Introduction to Computer Science"* offer for all departments in the university has some practical aspect, and nevertheless it was not a stand-alone practical course. This course, CSC107, provides fundamental computer skills required to follow and respond to an information technology (IT) driven learning process. Closed laboratory components have been a standard part of introductory courses in many undergraduate Computer Science programs. The laboratory in FUNAI operates in a closed format i.e. it is a lecture and practical/experimental arrangement (see Figure 1). We were able consolidated on the practical aspect using the lecture slides from the classroom for practical session throughout the first semester for CSC107. The laboratory was not particularly designed for CS majors but at least it served the beginning level practical purposes. The laboratory had the following for practical:

a. Desktop computer sets arranged in 'business centre fashion' i.e. in cubicles
b. Multimedia head gear for language translations

c. Keyboards and mouse

d. Flat screen monitors
e. White board and Project
f. Number of computers available for the practices was above 25

Laboratory environment generally requires the presence of instructor/s knowledgeable enough to help students through difficult parts of the assignment this was also available in FUNAI. In addition to the topics treated in Table 3 others include: PC configuration for optimized machine performance; Applications in Networking Protocols etc. The CSC107 topics treated is shown in Table 3:

Table 3: Lab Course CSC 107 - Practical Skills in Computer Science

Practical	***Topics Treated***
1st	PC Hardware (I/O & Comm. Devices and Ports)
2nd	Overview of Windows OS
3rd	Command Lines, System Threats: Protection & Security
4th	Troubleshooting, Backup and Restore
5th	Application Programs: Origin, Versions & Uses
6th	Elements of Effective Design I
7th	Elements of Effective Design II
8th	Elements of Effective Design III (border concept)
9th	Columns Layout /Text Wrapping and Graphics
10th	Shortcuts and Power Point presentation.

Table 4: Samples of Laboratory Experiment Scores

S/N	***ID No.***	***1st pract. 18/11/14***	***2nd pract. 25/11/14***	***3rd- pract. 02/12/14***	***4th- pract. 09/12/14***	***5th- pract. 16/12/14***	***6th- pract. 06/01/15***	***7th- pract. 13/01/15***	***8th- pract 27/1/15***	***9th- pract. 03/2/15***	***10th- pract 10/3/15***
1.	FunaiCSC001	60	70	40	60	50	50	65	70	80	75
2	FunaiCSC002	70	40	----	----	60	----	65	----	----	75
3	FunaiCSC003	60	----	----	60	60	70	40	----	60	65
4	FunaiCSC004	40	40	50	60	50	70	75	----	75	75
5	FunaiCSC005	50	70	85	70	60	70	70	70	70	70
6	FunaiCSC006	70	60	70	60	80	75	75	90	85	75
7	FunaiCSC007	50	40	70	80	70	60	75	----	65	75
8	FunaiCSC008	50	50	60	65	60	-----	----	----	-----	-----
9	FunaiCSC009	20	----	40	70	60	----	70	----	75	60
10	FunaiCSC010	60	70	50	75	50	----	40	50	55	75
11	FunaiCSC011	60	40	50	----	50	50	60	65	55	60
12	FunaiCSC012	60	60	40	40	50	-----	---	----	50	---
13	FunaiCSC013	----	----	40	60	75	70	75	60	75	70
14	FunaiCSC014	----	----	----	50	40	-----	---	----	40	40
15	FunaiCSC015	60	40	60	60	40	40	50	----	----	----
16	FunaiCSC016	----	40	----	60	70	-----	65	70	65	70

Sixteen (16) students who are Computer Science majors were involved in the practical classes handled and supervised by senior technologist *(*instructor*)*. The laboratory environment enables an individual student interacts with a single computer (see Figure 1). On the 1st through to the 3rd practical classes attended by within 12 -13 students, practical assignments were given which should be submitted in the next practical class, their performances and enthusiasm was above average. In the 4th through 5th practical classes attended by 14 students, practical assignments was also given, their performances and enthusiasm increased excellently i.e. above 80% scores. The 6th practical witnessed a drop in attendance by 9 students due to pressure from other courses, but their assignment scores remained high. The 7th practical class was attended by 13 students, the assignment score was above average. The 8th through the 10th practical classes recorded a very high score from the assignments i.e. 90%, averaging on 70%. The overall performances of the students showed:

i. That practical/experiments in the CS lab enhances the student understanding of the course of study.
ii. That students comes to grips with real world situation of their course of study during practical classes
iii. That practical should be encouraged especially at beginning levels of Computer Science course and at all levels because it is an important means for acquiring skills and knowledge.
iv. The laboratory practical performances of students reflected in their 1st semester final exam performances with A's, B's and C's while the less participating students got D's and F's.

Student Partnership in Laboratory

Knox et al. (1998) identified three modes of student partnership in laboratories: students working alone, students working in groups, and informal student consulting. These three models where allowed were necessary. The primary advantage of students working independently is that each student gets the same experience, while the advantage of students working in group is that they gain a deeper understanding of concepts and improve their communication skills, both of which are required by industry. Finally, the advantage of informal consultation among students is that students can increase their own understanding by helping others.

Some departments were reluctant to introduce this course at the moment because of excess credit load it will exert on the students' overall credit load although their students were very enthusiastic about taken the course. CS department has no choice rather than adjust its program and accommodate the new practical course. The outcome for such decision can only be seen in the practical life of the students. Moreover, students working in closed labs have the benefit of discussing their ideas, findings and problems both with other students and with the instructor. These opportunities do not exist in lectures or while working on standard homework assignments. The following are recommendations:

a. Students should be actively manipulating ideas as well as equipment when they engage in scientific investigation.

b. Students should be exposed to professional practice with current tools, resources, and emerging technologies used in the industry; and

c. Experience professional standards, ethics, and oral and written report styles common in the CS should be practiced by students from the first year of their studies.

Conclusion

This paper explores the need of using laboratories in teaching Computer Science as well as the redesign of the curriculum to accommodate practical at the first year (100 Level) of study as have been done in other disciplines. Laboratory experiences are recommended as an essential part of the undergraduate Computer Science program which must be reflected in the curriculum. We have presented a detailed collection of ideas regarding CS laboratory which will enhance the learning experiences of our students. We first reported the need for NUC to introduce a practical course on Computer Science with code CSC107 and CSC108 as introductory practical courses. We have already implemented CSC107 in our curriculum and we are working hard to introduce CSC108, however, this must pass through the proper channel such as the Senate. Our student expressed concern for the introduction of CSC108 after benefiting greatly from CSC107. We briefly mentioned samples of laboratory experiment scores of student assessment and this was a great experience for the students, however, we recognize the enormity of improving in the course contents of CSC107. The techniques suggested in this paper can be applied to other disciplines which offer students a guided path through an exploratory, discovery-based learning experience.

Correspondence
Onwudebelu Ugochukwu
Computer Science Department
Federal University Ndufu-Alike Ikwo
FUNAI P.M.B. 1010, Abakaliki
Ebonyi State, Nigeria
Email: anelectugocy@yahoo.com

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