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E-skilling on Fundamental ICT Networking Concepts – Overcoming the Resource Constraints at a South African University

A. Kayode Adesemowo and Mariana Gerber
School of Information and Communication Technology
Nelson Mandela Metropolitan University (NMMU),
Port Elizabeth, South Africa

kayode.adesemowo@nmmu.ac.za; **Mariana.Gerber@nmmu.ac.za**

Abstract

Year-on-year, the number of new learners entering higher education institutions continue to increase. This is positive when one considers government strategic interventions such as the ICT Policy and strategic intervention 4: Realizing Digital opportunity of the National Broadband Policy 2013 that highlights "uptake and use enabled through institutional capacity and individual capability and institutional absorption" as an intended outcome. Consequently, the demand for professional human resources to manage the broadband infrastructure at different levels increases.

However, higher education institutions are faced with the challenge of capital expenditure on technical equipment for training the ever growing number of first year students. As capital expenditure budget is lagging behind students intake (notably their skills practice need), it is imperative to investigate how best can higher education institutions leverage on limited resources to train students especially ICT students?

This paper posits that a visual ICT networking design and simulation platform, introduced as part of active learning rather than just open distance learning, provides assistance to higher education institutions faced with dilemmas of how to teach growing learners the foundational understanding of theoretical ICT networking concepts. The higher education institutions would not only be able to address the need for equitable ICT networking equipment, manage class interaction and assessment for rather large group but also leverage on the evidence-based advice from this study to efficiently train learners (future job seekers and/or e-astute citizens) that would be empowered to work effectively with technology.

Keywords: e-skilling, Large Classes, Learning, Active Teaching, Bloom's Taxonomy, Connectivism, Network Simulation, Packet Tracer.

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Introduction

There are an increasing number of initiatives in South Africa (SA) aiming to take advantage of the soon-to-be 'inherent' ubiquitous broadband pervasiveness, as an enabler to transforming lives and growing the Gross Domestic Product (GDP). Some of these initiatives include Tshwane Metropolitan's Project Isizwe (see projectisizwe.org), Western Cape Provincial Broadband Initiative (WCBBI) and the National Department of Communication (DoC) led SA Connect broadband policy (DoC National Broadband Policy, 2013) and ICT Policy (DoC National Integrated ICT Policy, 2014).

The ITU (International Telecommunication Union) acknowledged broadband technology as a contributor to economic growth at several levels (Katz, 2012). Qiang et al. of World Bank found that in low and medium income countries (such as South Africa), a 10% increase in broadband penetration yielded an additional 1.38% in GDP growth (Qiang, Rossotto, & Kimura, 2009). Whilst impact of broadband is absorbed to varying degree in different countries, broadband absorption drives intensive, productive use of ICT, online applications and services, thus making it possible to improve processes, introduce new models and structures, and drive innovation (Qiang et al., 2009). An intensive and productive use of ICT (apart from business strategic advantage) is seen in the increased engaged use of ICT by individuals and communities. Strategic intervention 4 (Realizing Digital opportunity) of the South Africa National Broadband Policy 2013 (DoC National Broadband Policy, 2013; Appendix), highlights "uptake and use enabled through institutional capacity and individual capability and institutional absorption" as an intended outcome. Parts of the metrics used for measuring these outcomes include:

- Increase demand side skills: ICT specialists …
- Number of PhDs in area of ICT

As broadband becomes ubiquitous, the demand for professional human resources to manage the broadband infrastructure at different levels of semi-skilled, skilled, expert and strategic level increases. To achieve on this, there is need for an increased post-school feeder of technical and undergraduate degree students specializing in technical and process elements of ICT, as well as leveraging ICT for business imperatives. As student numbers increase, so do the need for space, teaching aids and equipment they require for hands-on training in their study increase.

A problem faced by higher education institutions (HEI) is that with the increased number of students intakes, comes the requirement for more proportional ICT equipment for training (Sun, Wu, Zhang, & Yin, 2013). However, most institutions in South Africa are faced with budget constraints as capital expenditure (capex) on new and/or upgrade of equipment for students' hands-on skills practice is limited. Though a resource-challenge is universal, it is more pertinent in South Africa with its dual economy paradigm. This results in situation where there is limited resources to train the ever growing number of first-year students (especially ICT students). Consequentially, these institutions are faced with dilemmas of how to teach the growing number of learners with 1) apt learning and teaching for understanding abstract ICT networking concepts, 2) equitable ICT networking equipment to learn the networking concepts, and 3) managing class interaction and assessment for rather large groups. For ease of paper flow, the question arising and approach to studying these dilemmas are looked at in later sections: "Research Domain" and "Research Design".

Structure and Approach

In this paper, the elements of learning for understanding noting Bloom's learning taxonomy (Anderson, Krathwohl, & Bloom, 2001) and Connectivism (Conradie, 2013) are looked at. A visual network design and simulation platform was then reviewed as an appropriate platform for learning ICT networking concepts. Following is the mapping of learning for understanding with the visual network design and simulation platform at a university in South Africa. The study was partly based on Participatory Action Research (PAR) (Chevalier & Buckles, 2013) taking cognizance of Freire's critical pedagogy (consideration of how education can provide individuals with the tools to better themselves) (Howlett, 2013, p. 248). This paper concludes with an inference on the appropriateness of the platform as a learning tool to assist in achieving skills critical mass, required for effective broadband absorption.

Learning for Understanding: A Review

Year-on-year, the number of first year students entering the South African university system currently at one million circa (DHET, 2014, p. 7), is increasing at a rate that poses challenges for most universities in South Africa (Davids, 2014). With a growing student volume in class rooms, comes decreased student-tutor interaction and reliance towards large group teaching methods that tend to deliver information to a silent and passive student body (Surgenor, 2010). A notable strain comes to fore as the ever-expanding group of first-year students are taught with teaching aid resources that does not increase proportionally (Davids, 2014; Sun et al., 2013). In a number of universities in South Africa and the researched university in particular, students come from high schools where learning were more carefully controlled and structured through the school curriculum system (mini projects for some in grade 12). These students are then re-oriented to utterly different styles of teaching, learning and assessment (Surgenor, 2013, p. 289) when they get to university – a less structured environment than grade and high school. Added to this complexity, is the reality that students at South African higher education institutions (HEI) come from a variety of racial, cultural, linguistic and socio-economic backgrounds; such cross-cultural interactions and differences, even if mutually satisfying, may result in educational experiences and outcomes not being successfully achieved across board (Moutlana & Moloi, 2014, p. 53). The Department of Higher Education and Training (DHET) white paper (Jan 2014) mandates HEI to focus their attention on improving students throughput rates notably in scarce and critical skills needed for South Africa's economic development. ICT is one of these skills. A core component of the ICT skills especially relating to broadband is networking. How then can a large number of students be introduced to ICT networking; a foundation on which subsequent advanced ICT concepts are built?

Cognitive Learning

A view of the scholarship of teaching and learning is active learning/engagement (Moutlana & Moloi, 2014, p. 52). ICT has become a critical component of active engagement especially in blended learning (Conradie, 2013; DHET, 2014; Hauge & Riedel, 2012). Freire's critical pedagogy requires a revamping of traditional treatment of students as 'empty pots' that passively receive knowledge from authoritative teachers, to active engagement wherein students tend to learn, participate, explore and exhibit creative power and the ability to transform their own lives (Chevalier & Buckles, 2013; Howlett, 2013). Connectivism (as a combination of constructivism and cognitivism) could then be integrated as a component of blended learning environment to achieving active learning (Conradie, 2013). The learning environment must in effect provide students with progressive learning opportunity. In actual fact, face-to-face contact sessions must be supplemented with 'non-contact' connectivism (or online instruction) to achieve progressive learning. Not only will knowledge not be monopolized but also students engage in action learning (Chevalier & Buckles, 2013; Conradie, 2013; Moutlana & Moloi, 2014). Hence, this paper is not primarily focused on pure online learning, open distance learning (ODL) or massive open online curriculum (MOOC). Neither, does it explore the full spectrum of constructivism nor the specifics of connectivism (Siemens, 2005). It narrowed in on blended learning with particular focus on a platform that can be used to train students on the acquisition of ICT networking skills through the use of a ‘virtual’ environment rather than physical hardware equipment.

Learning Taxonomy

Educators have for long set learning objectives based on Bloom's taxonomy – including its revision and critique thereof (Anderson et al., 2001; Paul, 2012). It is broadly divided into three domains: cognitive (“knowing/head”), affective (“feeling/heart”), and psychomotor (“doing/hands”). Within these domains, it is expected that learning at the higher levels is dependent on having attained prerequisite knowledge and skills at lower levels (Orlich, Harder, Callahan, Trevisan, & Brown, 2012, p. 92). Bloom’s three domains and sub categories remain relevant in systematizing learning objectives. This in spite of other schools of thought such as critical pedagogy/thinking highlighting seemingly lack of systemic rationale of construction in Bloom’s three domains (Anderson et al., 2001; Paul, 2012, p. 519) and hence non-agreeing with the Bloom’s lower-to-higher level (sequential, hierarchical link). Paul (2012, p. 521) labeled this as “one-way hierarchy.

Research Domain

What is paramount then, is knowing how (large group) students develop and demonstrate understanding in a new knowledge field (Wiske & Breit, 2010, p. 7) such as ICT networking via the active learning sphere. Wiske and Breit (2010) reason that through a series of guided performances, teachers help students to gradually acquire new knowledge, along with the ability to apply knowledge in creating increasingly sophisticated products and performances.

An area found lacking in literature is how students learn particular facts in ICT networking and develop skills using a visual network design and simulation tool. Drawing from the research problem area and literature review of learning for understanding, a question to be asked is “as capex budget is lagging behind student intake (skills practice) need, how best can higher education institutions leverage on limited resources to train students especially ICT students?”

The research question then is “*can the use of visual network design and simulation platform substitute or complement physical equipment in skilling up large group first-year students in the fundamentals of ICT networking concepts*?” A derived question then would be “to what degree can the use of visual network design and simulation platform assist students in learning ICT concepts?”

Comparative learning using a visual network design and simulation tool and physical networking equipment or a mix of both, is excluded from this research. Equally out of scope is the positioning of learning in online learning and open distance learning. The actual level of skills acquired or the direct comparison of physical equipment to ‘virtual’ simulation are not the focus of this research study.

Visual Network Design and Simulation

The United Kingdom Open University (UKOU) offers its introductory ICT networking (T216) course to over 600 ‘experienced learners’ as part of a degree program (Moss & Smith, 2010). Unlike the UKOU T216, the foundational ICT networking course at the researched university is offered to over 350 students who were not expected to have prior knowledge of networking computers, their use in the workplace and basic ICT literacy skills. In fact, the students simultaneously take supporting courses in basic office productivity skills and IT essentials (learning about computer parts). The challenge that is faced is profound.

In the case of UKOU, students were able to (via NDG's NETLAB) remotely access and work on physical equipment in the lab. However, at the researched university, students are not provided access to physical equipment in their first year. Rather, they make use of visual networking and network simulators. The risk of 'breaking' or damaging expensive lab equipment are minimized especially by students who were inexperienced in using ICT equipment at the commencement of their first year at varsity.

Equally challenging is that concepts of ICT networking is theoretical and tend to be abstract in nature. Additionally, teaching where a higher level of students' imagination is necessary to understand advanced topics can be a daunting task in itself. Technology need to be leveraged on to scale hands-on 'equipment' availability to the large group and positively support learning without necessarily relying on technology in its entirety. Visual learning techniques provide a means to visually see how 'things' really work, to actively engage with it in progressive learning and for teachers to present the subject using animations and practical examples, rather than just talking about theory facts and formative assessment (Janitor, Jakab, & Kniewald, 2010).

Simulation and Learning

In the network technology field, practical hands-on skills are valued by potential employers (Makasiranondh, Maj, & Veal, 2010). With lab kits cost for ten students divided into five groups at over US$10000, most universities might not be able to afford the aggregated cost of providing dedicated network devices to student (Sun et al., 2013). Sample pricing available at Cisco Network Academy Program site (Cisco Academy, 2006). Network simulators and emulators have been used to teach technical and theoretical networking concepts (Breslau et al., 2000; Frezzo, Behrens, & Mislevy, 2009; Makasiranondh et al., 2010; Moss & Smith, 2010). Though there exists a difference between network simulators and emulators, offerings such as GNS3 combine both platforms, while OMNeT++ is a general purpose discrete event-based simulator (Weingartner, vom Lehn, & Wehrle, 2009) used for theoretical network protocol study. Other mixed platforms are commercial OPNET, Common Open Research Emulator (CORE), and hybrid ns2/ns3.

Studies by Breslau et al (2000), Frezzo et al (2009), Moss and Smith (2010) illustrate that network simulation platforms are able to address the needs of scalability of hardware experience, flexibility of hardware experience, visualization support for learning the abstract concepts and concrete skills of designing, configuring and maintaining data networks, and learning the inner working of ICT networking protocols. Frezzo et al (2009) further note that the Cisco Packet Tracer supports authoring and deployment of complex skill assessment (which is a key component of Bloom's taxonomy psychomotor).

Network Simulator Selection

Cisco Packet Tracer

The Cisco Packet Tracer (shown in Figure 1) is a network simulator that allows students to experiment with network behavior and ask "what if" questions. It is an integral part of the Cisco Networking Academy Program's (CNAP) comprehensive learning experience providing "simulation, visualization, authoring, assessment and collaboration capabilities." It further facilitates the teaching and learning of complex technology concepts (Cisco Academy, n.d.).

Graphical Network Simulator

The GNS3 network simulator is free and open source software (GNS3, n.d.), unlike Packet Tracer that is only free for students to use whilst they are a student of an academy. GNS3 presents network devices as ‘empty shells’, each requiring an ‘Operating System’ image to be loaded. As such for a student to work on a visual representation of a network device (for instance say a router) the actual image of the router must be loaded. For Cisco devices, it seems there might be a licensing violation. Nonetheless, GNS3 offers more choice of network devices that can be represented and hence more hands-on skills practice variety.

Network Simulator choice

Packet Tracer is used by choice because it is 1) the de-facto for CNAP, 2) easy to install (Windows and Linux) and a ‘get started’ platform for students that are just starting out in ICT networking.

Learning in Network Visualization and Simulation

The challenges faced with large groups of students learning ICT networking concepts included not only learning capability, teaching for understanding but also physical hands-on logistics. The lessons learnt are highlighted below with regard to alternate access to physical hands-on logistics by using a virtual networking design and simulation platform.

Research Design

355 students registered for the Networks-1 course at the beginning of the year. About two-thirds are new students in 2014 and the remaining are repeating students. The students were allocated into six lab practical groups according to the university’s lecturing time-table.

Hubball and Clarke (2010) who adapted participants’ observation (Kawulich, 2005; Mack, Woodsong, MacQueen, Guest, & Namey, 2005) from social science and medical research to scholarship of teaching and learning (SoTL), noted that appropriate combinations of qualitative (teaching and learning observations, student response feedback forms, participant narratives …) and quantitative (use of online learning tools, rating and rank-order preference scales …) data sources can yield reliable and critical information to enhance SoTL. In this paper, the visual networking design and simulation platform was used as a learning tool along with teaching and learning observation as qualitative data source. The primary quantitative data source is the questionnaire based ranked-order preference scales. Participants’ mini-narratives in the form of open-ended responses assisted in correlating observed responses with ranked responses, hence triangulating result findings.

The qualitative study utilized in this study involved 1) students’ usage of the visual network design and simulation platform, 2) researcher’s participation via observation and corrective actions. Students were gradually introduced to Packet Tracer as an ICT network design visualization and network simulator tool. Students were carefully observed (Chevalier & Buckles, 2013) for a semester duration. The “Introduction to Networking” course is nonetheless a year-long module. Per participatory action research (PAR) approach (notably participation observation), observations were made with corrective actions where required. The quantitative questionnaire study assisted in correlating the observations made during the qualitative study. Open ended questions were used to correlate student usage viewpoints, researchers’ observation and students’ responses to questionnaires.

Qualitative Study

The primary qualitative study in this research is based on participant observation which is a “process enabling researchers to learn about the activities of the people under study in the 'natural setting' through observing and participating in those actions.” (Kawulich, 2005) The observation was done in students’ ‘natural lab environment’ which takes place once a week over the duration of the course. Hence, there is no need for recruitment or selection of students as participants. Not only were students observed during their lab sessions, but requisite interventions were taken to address observed gaps per the principle of PAR.

Bringing up to speed: Students' introduction to Packet Tracer

In the first week of lab practical, students were welcomed and shown how to log into the Moodle "LEARN" site (basic web browsing exercise). In week two, they were introduced to the Packet Tracer 6.0.1 interface and help menu (content, tutorial), watched an introductory video and navigated the Packet Tracer program. Students were introduced to the Packet Tracer (PT) as a fun, take-home, flexible software program in week three. They then started engaging the Packet Tracer as a network simulator that emulates real life network environment. In week four, the students designed a basic network. They started viewing the Packet Tracer as a visual network design and simulation platform that allowed them to build network models, and ask "what if" questions.

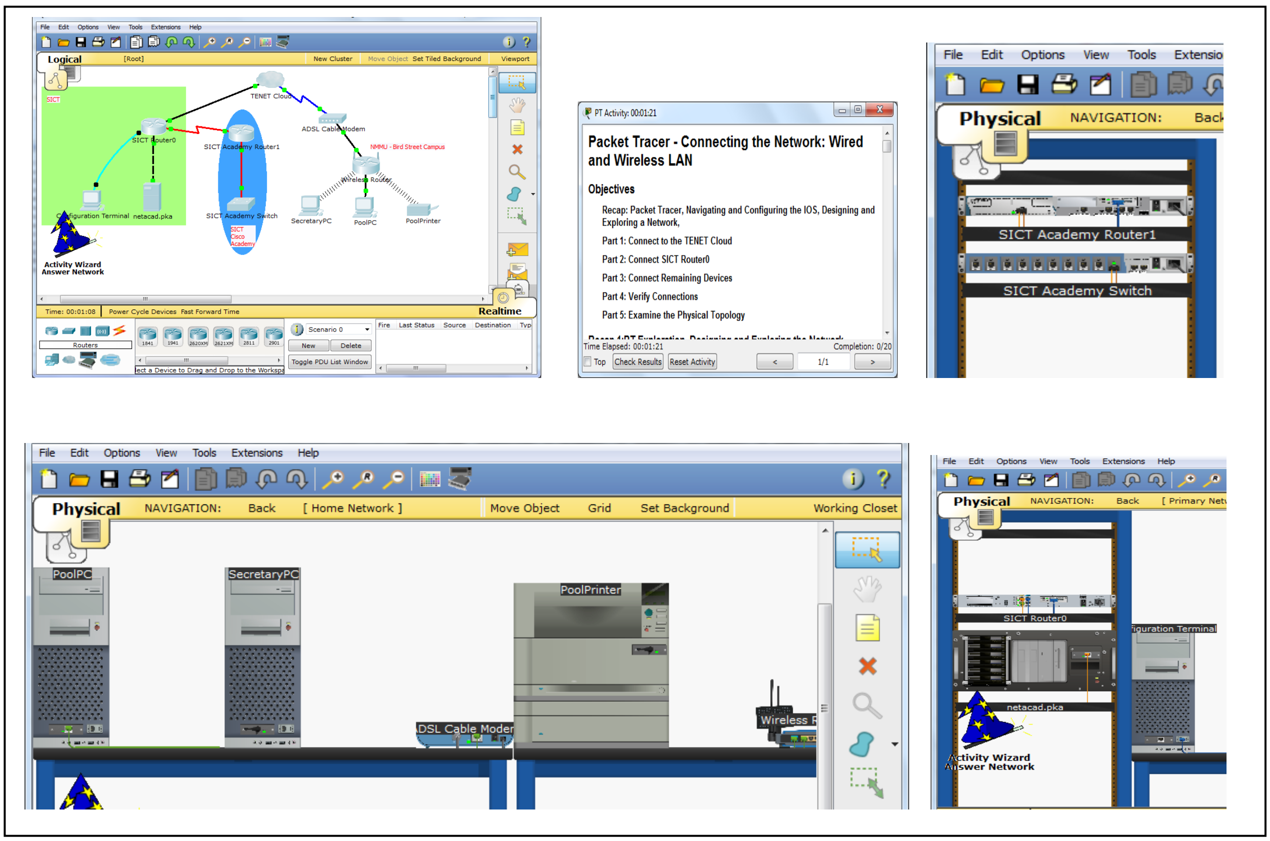


Figure 1 Packet Tracer lab activity teaching students OSI layer 1 and 2: how to connect wired and wireless network

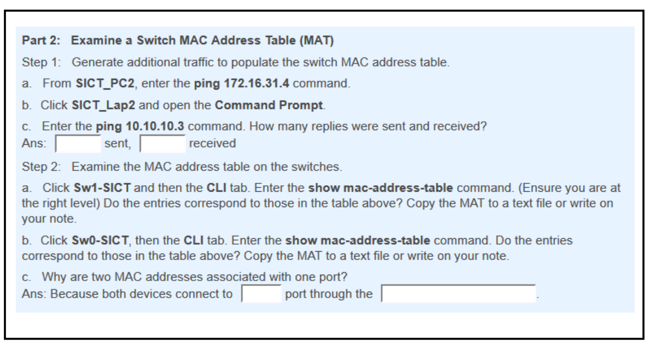
Shown in Figure 1, are some screenshots of the lab activities where students connect network end and intermediary devices using appropriate network media. They also drilled down to physical level to see the devices in cabinet rack in office computer room and table top at home. They then observed on the devices the network interface ports they were connecting to.

Observation of Students' use of Packet Tracer and interventions

The lab activity for week 2 was initially planned as part of week 1. However, it was observed that a sizeable number of the students struggled with basic IT tasks (in itself). This brings to the fore Moutlana and Moloi's (2014) stark reality of the complexity that South African HEIs face with respect to students coming from a variety of racial, cultural, linguistic and socio-economic backgrounds. Spreading the introductory lab activities over two weeks eased the students into the networking course.

Another participatory action research (Chevalier & Buckles, 2013) activity undertaken, was forcing attendance and participation in lab session activities through:

1. Enrollment into lab groups when student attended the lab session physically for the first time
2. Submission of lab activity Packet Tracer on the Moodle Learning Management System (LMS) based system at the end of each lab session. It was observed that certain students changed their fellow students' completed Packet Tracer file name and uploaded the file as theirs. The university has disciplinary measures in place to handle contravening acts in this regard. With the focus being on learning and teaching for understanding, other compensatory controls were introduced.
3. At the end of each lab session, the students took an online quiz based on the lab activities that they had just completed. Lab quizzes were refined over time to include lab hands-on and lab activity formative assessment questions as shown in Figure 2.
4. The implementation of an IP address lockdown ensured that students that were absent from the lab do not attempt the lab quiz from other locations. Students using their laptops in the lab had to give their IP address to the lecturer before being granted access to write the quiz.



Part 2: Examine a Switch MAC Address Table (MAT)

Step 1: Generate additional traffic to populate the switch MAC address table.

a. From **SICT_PC2**, enter the **ping 172.16.31.4** command.

b. Click **SICT_Lap2** and open the **Command Prompt**.

c. Enter the **ping 10.10.10.3** command. How many replies were sent and received?
Ans: ____ sent, ____ received

Step 2: Examine the MAC address table on the switches.

a. Click **Sw1-SICT** and then the **CLI** tab. Enter the **show mac-address-table** command. (Ensure you are at the right level) Do the entries correspond to those in the table above? Copy the MAT to a text file or write on your note.

b. Click **Sw0-SICT**, then the **CLI** tab. Enter the **show mac-address-table** command. Do the entries correspond to those in the table above? Copy the MAT to a text file or write on your note.

c. Why are two MAC addresses associated with one port?
Ans: Because both devices connect to ____ port through the ____.

Figure 2 Sample lab quiz asking direct question based on lab activity

5. Activity completion tracking was enabled in the Moodle based LMS that ensure that students download the lab activity Packet Tracer file before they could attempt the lab quiz and only then could they upload their completed Packet Tracer file.

The five learning interventions mentioned, were found to effectively increased student' engagement in lab activities and also lab attendance.

Quantitative: Survey

The networking course's purpose states that "*on completion of this subject, the student should have a solid grounding in the fundamental networking concepts and technologies. The student will have learnt both the practical and conceptual skills that build the foundation for understanding basic networking.*"

Questionnaire

The students were asked to complete an online questionnaire during their group's lab session towards the end of the first semester to further assist in correlating the observations made and participatory intervention actions. An eighteen (18) question questionnaire was carefully constructed on Moodle the Learning Management System (LMS). The questions are geared toward knowing when and which network simulators are in use, how the reported simulator is being put to use. Two hundred and fifteen students (n=215) completed the questionnaire during their weekly lab group session. Though their responses were received as "Anonymous", the system did not allow a student to take the questionnaire more than once. Further, students were only able to complete the questionnaire during their lab session when they are physically present. This approach ensures that responses are valid responses from intended students and not from possible 'unknowns'.

Questionnaire result: Students' use and experience of PT

When asked if they "have used Packet Tracer (PT) before 2014", about two-third (67%) replied "No". A further probing question indicated that about a third (31%) have used PT before the commencement of the networking course because they are repeating the course. It is imperative to gain insight into students' engagement with PT.

Three-fifth responded that they "own a PC/laptop or have access to a dedicated PC/laptop and have PT installed" indicating possible personal usage. The majority of these respondents listed PT version 6.0.1 as their installed version (latest version at the time). A natural progression then would be to know how they put PT to use.

A response of 41% who on average use PT once a week after lab sessions and 15% twice a week might not be encouraging but does give an indication of after-hour usage. This is supported by a shift towards a likert scale "agree" score by over two-third of respondent of PT (lab activity instruction) facilitating learning technical networking concepts as seen in Figure 3.

PT Activity window
1 (does not), 2 (limited learning), 3 (do not think so), 4 (agree), 5 (definitely Yes/Ja/Ewe)
Allow me to learn networking concept on my own 3.4
Provide guidance I need to learn 3.7

PT network simulator
None (1) | Low(2) | Moderate(3) | High(4) | Very High (5)
confidence level in exploring networking concept 2.8
confidence level in designing basic networking 3.0

Moderate (3) | Yes to some extent (4) | Definitely Yes (5)
facilitate learning technical network concepts 3.0

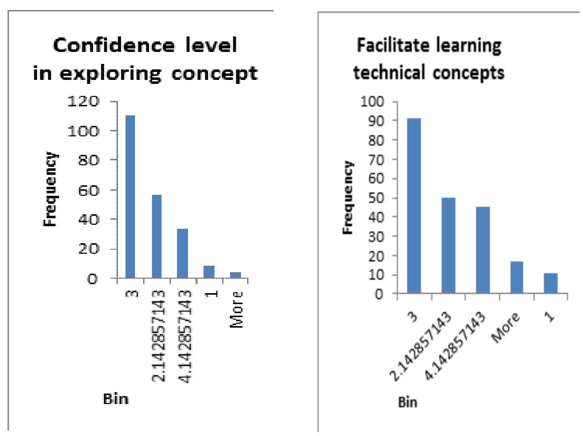


Figure 3 Questionnaire response on visual learning in Packet Tracer

In Figure 3, the *3.4* (likert scale score) is of essence as this can be construed to imply that other learning modes are required. The students have a two lecture period contact time for lecturing (one hour and twenty minutes) with the lecturer and supplementary teaching (voluntary) of one hour weekly with a senior tutor (a PhD student). The gradual shift away from the middle *3.0* towards the *4.0* agree (likert scale score) shows that with more targeted Packet Tracer activities, the students might be able to leverage Packet Tracer even more. This is important as a *2.8* (likert scale score) of students' confidence level in exploring networking concept through the use of

Packet Tracer is not strong enough. Just a little above 50% have a moderate and 16% high confidence level.

Regardless, Packet Tracer is seen as moderately increasing students' confidence in exploring ICT networking concepts and visually designing ICT network topology. Though moderate, the authors concur with Janitor et al.'s (2010) visual learning technique that Packet Tracer visually facilitates the learning of technical ICT networking concepts. Hence, a visual learning technique provides a means to visually see how 'things' really work and to actively engage with it in a progressive learning style. Visual learning include video animation, drag-n-drop, what-you-see-is-what-you-get among other supports. Visual learning techniques supported by Packet Tracer are the visual design of networking topology ('realtime mode') and the visual inspection of networking events ('simulation mode'). It is recommended that more activities be carefully designed in this regard. Packet Tracer allows a lecturer to design experimental activities for students to do during lab sessions and also to take away with them after the lab session to further practice with on their own.

In Week 9 lab, navigating to physical mode in PT assisted me in understanding how to physically wired a network device better

Moderate (3) | Yes to some extent (4) | Definitely Yes (5)

Gain understanding of OSI Layer 1	**2.9**
Physical Copper Straight-through cable	**3.4**
Physical Copper Cross-over cable	**3.4**
Physical Fiber Cabling	**3.3**
Wireless network media	**3.3**
Physical placement of devices in cabinet rack …	**2.9**
Physical placement of devices on table top …	**2.9**

Figure 4 Visual learning of OSI layer 1 and 2 in PT

Contrary to the opinion that network simulators such as Packet Tracer does not provide students with important practical skills, such as cabling and physical connectivity, the students' engagement with Packet Tracer via the "Physical view" shown in Figure 1 provided them with some insightful knowledge of the Open Systems Interconnection (OSI) layer 1 and 2 concepts (Frezzo et al., 2009, p. 108; Makasiranondh et al., 2010, p. 321). Students' responses in Figure 4 indicate that they do not feel totally disadvantaged learning about network media. This is evidenced in the physical layout of SICT Academy Router1 and SICT Academy Switch on the Rack in Figure 1, constructed during lab session. Nevertheless, wiring up network devices and network media (especially cable) termination are skills that must still be experienced physically!

Correlating Qualitative with Quantitative

Below are some of the open comment responses (as-is) provided from students' viewpoints.

"I have a lot of interest in Packet Tracer and i would like to learn more about it"

"PT Played a vital role on helping me to understand the networks better."

"I don't understand it because I don't have enough time to practice and network notes are too long but I will strive and do my best to pass."

"more time needs to be dedicated to command prompts"

"HOW ABOUT WE BE GIVEN ENOUGH TIME TO WORK ON PT PRACS AND QUIZES (sic) !!!!!!!!!!!!!!!!!!!"

"I am still finding it difficult to do packet tracer sometimes because its (sic) too fast and I am a bit slow when it comes to networks and actual seeing what is needed in a curtain (sic) activity"

"i am struggling to learn and understand packet tracer."

Students' open ended responses provided some insight into how they responded to the questionnaire and their perception of the usefulness of Packet Tracer (the selected visual network and simulation platform).

Students view Packet Tracer as a visual network design and simulation platform of interest that better assists them in learning about and understanding ICT networking. Prior to the time of the survey (completed after their lab session), students submitted their completed Packet Tracer file (lab activity). This might have resulted in some of them 'racing' through the lab activity rather than engaging Packet Tracer to learn the objectives of the lab activity. It is no wonder then that some of the students have raised this in their responses. A corrective action taken thereafter was to ensure that students attempted the lab quiz before leaving the lab and only those who were in the lab and attempted the lab quiz were able to submit their Packet Tracer file later in the week, thereby giving them enough (and extra) time for their weekly lab activities.

Comments such as "*struggling to learn and understand packet tracer*", among others, correlate well with the mid-range responses seen in the survey. It can be deduced that leaving students alone to learn networking via Packet Tracer would be unsuitable for learning (in its entirety, especially in an open distance learning). They must still be guided during lab activity, as is done (and should be increasingly done). More so, there must be greater alignment between lectures on concepts and practical sessions on the concepts.

From this research study, it can be shown that the use of a visual network design and simulation platform does not yet substitute for, but rather currently complement physical equipment in skilling up large group first-year students in fundamental of ICT networking concept. However, careful introduction of a visual network design and simulation platform does assist students in learning ICT concepts to some noticeable extent, as seen in 1) Figure 3, 2) the open-ended responses and 3) direct observation of students (participants). In addition, just-in-time assistance and interventions must be provided to the students during lab hands-on sessions. Students must nevertheless still be able to think with this knowledge and apply it in creative ways to transform their own lives (per principle of critical pedagogy and connectivism).

Five corrective learning interventions were highlighted earlier under the Qualitative Study section. Such interventions are required to optimize the usage of a visual network learning and simulation platform. It is imperative that through 1) careful planning, 2) targeted lab activity instruction, 3) encouraged active usage, 4) just-in-time learning interventions, and 5) visual network design and network simulators (such as Packet Tracer), learners will be assisted in learning ICT networking concept (and ICT in general). Nonetheless, for low-level networking investigation, other discrete-event network simulators such as OMNet++, NS3 et al might be more appropriate.

Conclusion

The ICT industry (DoC National Broadband Policy, 2013, p. 34; DOC National Integrated ICT Policy, 2014, p. 54) and Internet of Things or Internet of Everything (Mahoney & LeHong, 2012) globally powered by ubiquitous broadband has necessitated the need for a skills feeder (ICT networking critical mass). Post-school training providers especially universities are faced with large first year classes (in excess of two hundred and sometimes more than five hundred). Yet, availability of ICT training kits is not growing at the same proportional rate. Integrating visual network design and simulation platforms into active learning/engagement at these institutions would assist in facilitating appropriate foundational and functional ICT networking skills development. The optimal usage of the platforms does ensure that knowledge is passed on to the much desired ICT professionals of the future. DoC (inclusive of South African iKamva National e-Skills Institute (iNeSI)) and DHET are able to deliver on their mandate of skills development to support (DHET, 2014; DoC National Broadband Policy, 2013) and use the accelerated broadband infrastructure.

Active involvement of the lecturer, as is typical in other participatory action research studies (Chevalier & Buckles, 2013; Kawulich, 2005; Mack et al., 2005), might be conceived as introducing elements of bias, which may impact on objectivity. This was mitigated by a clear objective and correlation of observation with questionnaire. Another limitation to also note is that there still exists some sort of authoritative learning outside the simulation platform as students are still guided by a lecturer. This is a limitation per principle of connectivism though essential per the research finding. Nonetheless, the focus of the research is the degree of learning (ICT networking fundamental and skills) that possibly takes place while using the simulation platform when physical networking kits are not available due to low capex funding.

Future longitudinal and participatory action research studies could assist in further seeking to ascertain if taking of labs using Packet Tracer challenges students, to establish how far the students are challenged, and also how the use of the network simulator builds their confidence. A comparative study of the use of alternate network simulators (and physical devices) as part of future research may assist in a multi-dimensional viewpoint.

Though the use of a simulation platform is not entirely new in higher education institutions, the careful incorporation of visual network design and simulation platform into the teaching of learners that are new to ICT networking is a contribution that most higher education institutions would find useful as they battle with increasing costs of physical equipment to train the ever growing number of first-year learners.

In the current iteration, the use of a visual network design and simulation platform cannot be seen as ‘the’ outright replacement for physical training kits. Rather, its careful integration as part of blended learning (active teaching) approach, is a starting point that would improve e-skilling. Further research into the dependence on the student's urge to learn more about the subject field and willingness to use a new platform to learn, will be important in teaching pedagogy.

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Appendix

SAMPLE QUESTIONNAIRE RESPONSE:

View All Responses **View By Response**

Summary Print this Response Delete this Response

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 |
64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109
120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 | 144 | 145 | Next

Respondent: - **Anonymous** -

Cisco Packet Tracer Questionnaire:

*1
I have used Packet Tracer (PT) before 2014: Yes | No

( ) Yes (•) **No**

2
I used PT before 2014 because I used PT for Networks 1 (or previous) course in 2013 or earlier. Yes | No

( ) Yes ( ) No

*3
I have use a network simulator/emulator before 2014: Yes | No

(A network simulator such as Cisco Packet Tracer allows you to design network topology and explore networking events and protocols)

( ) Yes (•) **No**

4
I have use the following network simulator before 2014.

Kindly list the one(s) have you used before? List them below

*5
I own a PC/laptop or have access to a dedicated PC/laptop and I have PT installed

PT = Packet Tracer

(•) **Yes** ( ) No

6
If you owned a PC/laptop or have access to a dedicated PC/laptop and you have PT installed, what version(s) of PT do you have installed

*7
On average, how often do you use PT on a weekly bases?

( ) I do not use on a weekly bases
(•) **once a week**
( ) twice a week
( ) thrice a week
( ) more than four times a week

*8
On average, how often do you use PT after the lab session on a weekly bases?

( ) I do not use after the lab session
(•) **once a week**
( ) twice a week
( ) thrice a week
( ) more than five times a week

Biographies

A. Kayode Adesemowo is a Chartered Engineer and information assurance advisor with extensive industry experience and certification. He received his masters by research computer science degree in 2007 from the University of the Western Cape and presently studying towards his PhD at the Nelson Mandela Metropolitan University where he works as a lecturer lecturing in the area of networking and security. His research interests include assets, information security, governance, risk, audit, project assurance and ICTD.

Dr Mariana Gerber holds a PhD-degree from the Nelson Mandela Metropolitan University. She is a Senior Lecturer and has been lecturing in the Department of Information Technology at the Nelson Mandela Metropolitan University for more than 16 years. Mariana has been actively involved with research activities and post-graduate student supervision in the field of Information Security Management and Governance for several years. Mariana has published and presented a number of papers in the field of Information Security in journals and conferences, nationally and internationally. She is a member of the ISACA and holds a Certified Information Security Manager (CISM) professional registration.