

Empirical Study of Digital Poverty: A Case Study of a University of Technology in South Africa

Watson Manduna

*School of Teacher Education, Faculty of Humanities, Central University of Technology,
Free State, 20 President Brand Street, Bloemfontein 9300, South Africa
E-mail: wmanduna@cut.ac.za*

KEYWORDS Digital Barrier. Digital Deficiency Framework. Economically Empowered. Information and Communications Technology Usage. Social Gap. Digital Haves and Have Nots

ABSTRACT This research evaluates the availability and use of Information and Communications Technology (ICT) by students from disadvantaged and privileged families studying Computer Science at a University of Technology in South Africa. A questionnaire was distributed to a stratified random sample of 50 first- and 20 third-year students. Descriptive statistics were used to analyze and present the results of the study. The results suggested that a low level of education is associated with digitally poor people. Results of the research also proposed that men had more opportunities of using ICTs than women. The more economically poor a family was, the more digital poor it was. The research also showed that living in the rural areas seems to decrease the probability of being (more) digitalized. The results of the study were later used to create a framework for assessing the degree of ICT usage and to group the population into digital poverty levels.

INTRODUCTION

The emergence of information and communication technologies (ICT) has greatly impacted the socio-economic and political activities of individuals, organizations and nations (Chen and Zhu 2004). In education, students who managed to harness this technology have amplified their active, evaluative, integrative, creative and collaborative learning capabilities (Hong et al. 2003; Tinio 2003; Zaidieh and Jalal 2012). For example, there is ample documentation on the use of the Internet as a source of information for literature reviews, authors' searches, subject searches, and research (Luambano and Nawe 2004; Rehman and Ramzy 2004; Nwagwu et al. 2009). There are reports on the gains brought about by networked computers where information is obtained by anyone from anywhere and at any time (Tinio 2003; Siti et al. 2009), leaving those with no or limited access, availability and accessibility to computers behind. Consequently, this created and/or broadened the socio-economic and political gap between the 'haves' and the 'have nots'.

Types of ICT Usage Studies

Research on ICT use was done using a micro-sample of individuals in a given country (Ono et al. 2007), micro-samples of individuals' groups in given countries (Demoussis and Giannako-

poulos 2006; Vicente et al. 2006a; Quibria et al. 2003), macro-samples of developing, underdeveloped and developed countries, and single measures like one computer per 1000 inhabitants (Demoussis and Giannakopoulos 2006) or Internet users as proxy of the digital level of countries (Gutiérrez and Gamboa 2008).

Results of some of the research done provided accounts about the digital divide or inequality in developing countries, developed and underdeveloped countries (Fuchs and Horak 2008; Gebremichael and Jackson 2006; Ugas and Cedros 2007; Mariscal 2005). Accordingly, this research used a micro study to assess the availability and use of ICT by 50 first- and 20 third-year students from disadvantaged and privileged families studying Computer Science at a university in South Africa.

Socio-economic and Political Environment

Some students at this specific South African university struggle to access and use ICTs to enhance their learning capabilities, while others access and use ICT with ease. The reason for this discrepancy may be because of divergent socio-economic and political backgrounds. Different scholars have proposed different views on the causes of these discrepancies. In sub-Saharan Africa (SSA), for example, socio-economic and political challenges have directly contributed to such inconsistencies. For example, the monopolization of telecommunications sys-

tems and broadcasting networks by the government has hindered the possibility of outside investment by restricting ICT sustainability in the private sector (Gebremichael et al. 2006).

Research done on poverty demonstrates that it can take many dimensions (Dollar and Kraay 2000; Ravallion 2000; Trieghaardt 2006). For example, Ravallion (2000) defines the absolute criterion of living on USD 1 or USD 2 per day as a line to identify the poor. This research adopted the definition of poverty by Trieghaardt (2006), which includes absolute poverty, moderate and relative poverty. It is against this background that this study sought to investigate how poverty, education, geographical location, gender and employment predict ICT access, availability and accessibility.

RESEARCH METHODOLOGY

Research Design

A specific research design was used as a way of providing a blueprint for conducting the study that would produce information aligned to the research (Burns and Grove 2001). This study used a combination of quantitative and qualitative approach methodology to identify, analyze and describe how poverty predicts ICT access, availability and accessibility.

Instruments

The choice of quantitative methodology was guided by the need to quantify and conduct a statistical examination of the data so as to reduce and organize it, determine significant relationships and identify differences and/or resemblances within and between distinct data classes. On the other hand, qualitative methodology was used as a way of obtaining data to explore, describe and gain an in-depth understanding of participants' behavior on ICT usage and the reasons for that behavior.

Population and Sample

A stratified random sampling method was used for this study because it provides greater precision than a simple random sample of the same size, thus providing a guarantee of a balanced sample. Accordingly, as depicted in Table 1, fifty first-year Computer Science students and twenty third-year Computer Science students were used as the study sample.

Table 1: Demographics of the sample of the first and third year computer science students

<i>Level of education</i>	<i>First year students</i>		<i>Third year students</i>	
	<i>Female</i>	<i>Male</i>	<i>Female</i>	<i>Male</i>
Gender	32	18	13	7

Data Collection

Data was collected from a questionnaire, which was designed with both open and closed-ended questions. The instrument was distributed during normal lessons and respondents were asked to respond and submit the questionnaire at a time convenient to them. From each respondent, the research extracted information on age, gender, family income, education level, labor status and their ICTs pattern usage. This helped to:

1. Identify factors that influenced the use of ICT,
2. Quantify students' socio-economic status versus their ICT proficiency,
3. Evaluate the degree of university and after university usage of ICT by the students,
4. Group the population into digital poverty levels.

Ethical Issues

Ethical issues were considered and permission was obtained from the administrators. Enough care was taken to make sure that any potential risk or harm to participants was avoided or limited. It was also clearly stated in the questionnaire that answers provided by the respondents would remain confidential, protected and would solely be used for that research.

RESULTS

Collected data was analyzed using tabulated frequency counts and percentages, and the findings were presented by use of descriptive statistics.

Demographics of ICT Usage

Rural and Town

The research disclosed that 37.1 percent of the respondents came from the city and 62.9 percent from rural areas. From that composition,

Table 2 was used to illustrate the students' sentiments on the availability of ICT tools in towns and rural areas.

Table 2: Response of students on the availability of ICT tools in rural areas and cities/town

Availability	Rural areas		Town or city	
	No	Yes	Yes	No
Public telephones	40	3	27	0
Internet cafes	43	0	26	1
Network coverage (cell phone)	39	4	27	0
Roads	37	6	27	0
Clean water	30	13	22	5
Schools	29	14	23	4
Technical people	38	5	22	5
Shopping markets	33	10	27	0
Clinic and or hospital	29	14	24	3
Electricity	30	13	27	0

Available Income versus Expenses

Results showed that there was a wide financial discrepancy among the respondents' parents and/or guardians. Classifying students according to their parents' or guardians' income levels revealed that 58.6 percent of the students' parents or guardians were poorly remunerated, 28.6 percent were averagely remunerated whilst 12.8 percent were well paid. It was also discovered that many families/individuals had many other expenses (many dependents, rent obligations and so on), which eroded their salaries when summed together. Thus when asked about their social status, 68.6 percent of the respondents strongly agreed that their immediate family members were poor, whilst 22.9 percent partially agreed and 8.5 percent disagreed. More than fifty percent (55.7%) of the respondents strongly agreed that their close friends were poor, whilst 27.2 percent agreed and 17.1 percent did not agree with the statement.

To demonstrate the divergence of their social status, the research also used Table 3 to reveal the capabilities of the respondents' family members to meet their financial obligations.

Table 3: Observations of challenges faced by some of the students' family members (%)

Family member(s) who had problems in	Yes	No
Payment of rent or mortgage	81.4	18.6
Money for transport to go to School	65.7	34.3
Money for food	75.7	24.3

When the respondents were asked to evaluate the properties they lived in at home (when the university is closed), 64.3 percent pointed out that they lived in a property valued at less than R20,000, 24.3 percent between R200,001 and R300,000, and 11.4 percent above R300,000. The study also revealed that 78.6 percent of the respondents rented their accommodation (at the university) due to the fact that they came from other provinces, thus putting extra cost to already overburdened parent(s) and or guardians, while 8.6 percent lived with their guardians and 12.8 percent with their parents.

Results indicated that students' bursaries were offered for many reasons. For example, some were offered on the basis of an individual's academic excellence, whilst others were given on the bases of affordability. This research proposed that bursaries were offered based on the condition of affordability. As such, Table 4 was used to depict different sources of funds for fees and accommodation for the students.

Table 4: Views of the respondents on the source of fees and accommodation

	Fees paid by (%)	Rent paid by (%)
Parents	21.4	23.6
Guardian	11.4	16.4
Bursary	67.2	60.0

To further probe the degree of access the students had to ICT tools (Table 5), this research investigated whether students had a computer, a computer connected to the Internet, webcam and printing facilities at their current residence, or at home when the university was closed.

Gender, Level of Education and Unemployment

This research also used gender as a variable to validate differences in ICT usage. Results showed that during the school holidays 35.7 percent of the respondents lived with their mothers only, 14.3 percent with their fathers only, 25.7 percent with both parents, and 24.3 percent with guardians. Statistics revealed that 66.6 percent of the respondents' female relatives were either unemployed, or temporarily employed.

Results showed that 18.6 percent of the respondents' relatives did not attend Grade 12, 38.6 percent attended only Grade 12, 27.1 percent had diplomas and 15.7 percent had degrees.

Table 5: ICT Items owned by students

<i>Item</i>	<i>Computer</i>		<i>Computer connected to the Internet</i>		<i>Printing facilities</i>		<i>Web camera</i>	
	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>	<i>Yes</i>	<i>No</i>
Available at the current residence	13	57	9	61	5	65	1	69
At home when the university is closed	7	63	6	64	3	67	0	70

Meanwhile, it was noted that all 68.6 percent of respondents' relatives without Grade 12 education were poor and had never used any computer. Respondents' relatives with Grade 12 education (22.9%) were observed to have used computers and were relatively poor, whilst 8.5 percent of respondents' relatives with diplomas and degrees were not poor and indicated that they had used computers.

Existence of an ICT Policy

All the respondents noted that they were not aware of any ICT policy governing the deployment and use of ICT at the university.

DISCUSSION

Determinants of ICT usage vary according to different individuals and their situations. Thus it is imperative to determine how and why one group is able and the other one unable to adopt, access, and use ICT. For example, one can have an ICT gadget but its use can be limited by the unavailability of electricity, time, human capital, commitments, low level of education, a high degree of illiteracy, or age (Cáceres 2007). For example, Adelzadeh (2006) and Kasusse (2005) viewed age, gender, rural and urban areas, unemployment, ignorance, illiteracy, poverty, and other forms of marginalization as barriers to ICT use. Meanwhile, the study done in Western countries by Ono (2006) found out that there is no gender divide on ICT use. Rice and Katz (2003) discovered that income and age gap may feature as ICT inhibitors, but gender and race were not seen as major factors in the determination of ICT use. On the other hand, Gutiérrez and Gamboa (2008) observed age as a contributing factor to the use of ICT. However, this research revealed that age does not play a major role, because as indicated by the results, about half of the respondents' guardians had access to

applications such as Facebook and WhatsApp through their smartphones and where using them.

Similar results were found in studies done by Gebremichael et al. (2006) and Kebede (2004) who noted the heterogeneous nature of language in the sub-Saharan as a hindrance to ICT. This research however, noted an improvement in literacy level of the respondents' guardians or parents such that it was speculated that usability and accessibility to ICTs was enabled.

Results indicated that a large proportion of the respondents came from rural areas where there were limited resources like personal finances, infrastructural development, trained ICT staff as well as limited ICT infrastructure. These barriers may have excluded residents in those areas from getting access to ICTs tools.

To validate the dissimilarity of social status of people, this research considered the financial status of the respondents, their immediate relatives and friends. Firstly, the research noted a wide gap between the poor and the rich students. This was further evidenced by the existence of a wide financial discrepancy among the respondents' parents and/or guardians. The huge variation in their social status was also evidenced by the following factors, that is, many lived in shacks (those who lived in towns), homelessness, unemployment, poor infrastructure and lack of access to basic services (Table 2), and the incapability of the respondents' family members to meet their financial obligations (Table 3). Many students depended on bursaries, because the majority of them could not afford to pay for their own rent (accommodation), fees and food (Table 3). This affirmation concurs with Adelzadeh (2006), who argues that almost half of the South African (SA) population lived under a poverty datum line. Consequently, the population is divided between those who have and those who have not used ICT (Adeogun 2003). Those with no or little income, without food and

other basic needs were therefore not expected to buy, rent or use any ICT related component if basic needs are not met (Fuchs and Horak 2008). This view is supported by the respondents' sentiments when questioned about their choice between food and computers, as many of them selected food. They believe that basic problems such as poverty, health issues, and illiteracy have to be tackled first (Fuchs and Horak 2008). Costs and maintenance of ICT tools also played a major role in the determination of its usage and accessibility (Gebremichael et al. 2006; Kebede 2004; Demoussis and Giannakopoulos 2006). For example, an average computer costs R3,200, and yet some the students' and or their guardians' had monthly expenses that superseded R3,200 and an income of less than R3,200.

This research considered the relationship that exists between poverty, income and employment (formal or informal) as determinants of ICT usage. As noted, if the salary was low or there was no source of income, chances of affording basic goods was very little, thus minimizing the possibility of owning and/or using ICT. On the other hand, those employed, with decent salaries and wages, were able to fulfill their basic needs and able to buy or rent ICT tools. This divide was then made wider as a result of the differences in expendable income.

The research proved a gender digitalization gap (Gutiérrez and Gamboa 2008), characterized by the existence of two classes (Makgetla 2004) divided according to gender. Following a tradition of male domination (where the majority of women were either temporarily employed, unemployed or have a lot of household chores to attend to) and the fact that ICT access is mostly performed in the public domain and not at home, one can therefore conclude that the probability of ICT usage by 35.7 percent of the respondents who lived with their mothers were very low.

It is also speculated that people with high levels of education and income tend to have access to ICTs, compared to those with low levels of education (Van Dijk 2006; Fuchs and Horak 2008; Gutiérrez and Gamboa 2008; Demoussis and Giannakopoulos 2006; Vicente and López 2006b; Ono 2006; Chinn et al. 2007).

Digital Poverty Framework

It is difficult to have a clear picture of the digital divide because there is no universal def-

inition available (Gebremichael et al. 2006). For example, Castells (2002) defines it as inequality of access to the Internet, while Norris (2001) and Wilson (2006) regard it as uneven access, distribution, and use of ICT between two or more populations. Van Dijk (2006); Hargittai and Eszter (2003) consider it as a gap between those who have and do not have access to ICTs. This research considered arguments proposed by Dimaggio et al. (2001) and Fuchs and Horak (2008) on the digital divide, which includes inequalities in access to the Internet, extent of use, knowledge of search strategies, quality of technical connections and social support, ability to evaluate the quality of information, and diversity of uses.

Following the results and discussions of the empirical research done, this segment formulates a digital poverty framework (Fig. 1) based on socio-demographic data obtained. Reference is made to Trieghaardt's (2006) definition of poverty, which includes absolute poverty, moderate poverty and relative poverty.

The researchers can thus loosely consider digital poverty as an interlink of absolute, moderate, relative ICT poverty where,

Digital Poverty = Absolute ICT poverty + Moderate ICT poverty + Relative ICT poverty.

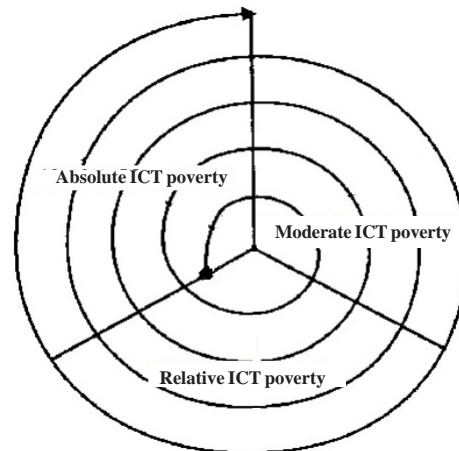


Fig. 1. Empirical evaluation of the digital poverty
Source: Author

Absolute ICT Poverty

This category is made up of people who do not have access to ICTs tools such as the Internet, computers and smartphones. In most cas-

es, failure to get access to these ICT is contributed to the unavailability or lack of physiological needs (Fuchs and Horak 2008). These include food, drink, shelter (Sachs 2005: 20), safety, healthcare, warmth, disability, sex, sleep, sanitation, clothing and proper education for some or all children. Coupled with this are low annual incomes, few household assets, support for dependents, and obsolete and/or low levels of education. Usually, focus is on the absence of physical, technical, and economic features that produce classes of winners and losers of the information society (Fuchs and Horak 2008). Physical aspects include roads, pathways, doors, libraries, schools, post offices, hardware, software applications and networks, which must be kept up to standard (Fuchs and Horak 2008). Technical proficiency includes capabilities to operate ICT hardware and applications. Economic traits (benefit access) embrace gains (active, evaluative, integrative, creative and collaborative capabilities) acquired by individuals and the society through ICT usage.

Moderate ICT Poverty

This section comprises people who sometimes fail to meet basic needs. Household income level is below a given proportion of average national income and as such, access to ICT is limited. Access is limited to availability (the proportion of time a system, subsystem, or equipment is in a functioning condition or operable state until it is called off). They periodically use ICTs tools such as Internet and smartphones.

Relative ICT Poverty

This group has got many ICT tools but information is sometimes not relevant and not presented to the widest possible audience due to the lack of proper design and implementation of a user-centered holistic approach. In most cases, this group has basic goods and services but ICT usage is hindered by social (disabilities, gender, race, family status, age, ethnicity, origin, language) and geographic (urban/rural), political or economic divides.

CONCLUSION

The research confirmed the relevance of aspects such as poverty, education, geographical

location, gender and income in explaining the gap in the access and use of ICT. The contribution of this study to the line of research in ICTs is the novel empirical evaluation of digital poverty in the dimension of access, accessibility and availability. To that extent, factors that explain the access and use of ICTs in South African contexts are explored. This has enabled the research to derive a novel definition of digital poverty.

RECOMMENDATIONS

The research recommends that a coherent, broad-based, relevant and all-encompassing ICT policy framework with a sustainable implementation, integration and learning structure be implemented. To ensure equitable ICT access and usage, a thorough consideration of social demographic elements that can be used to inform policy formulation should be considered. The engagement of the community in planning and designing ICT-supported interventions should be encouraged. The research also proposes that technology infrastructure, technical support, access and accessibility of ICTs and ICT related components must be made available, irrespective of one's social, economic, and political background. The research has noted costs associated with having landlines and desktop computers, which makes it difficult to reach the majority of people in rural areas, consequently use of Wireless Fidelity (WiFi) is proposed.

REFERENCES

- Adelzadeh A 2006. *Overcoming Unemployment. Strategies for Giving the Effect to the Right to Work*. District Six Museum. Cape Town: Alternate Information Development Centre.
- Adeogun M 2003. The digital divide and university systems in Sub-Saharan Africa. *African Journal of Library, Archives and Information Science*, 13(1): 11–20.
- Burns N, Grove SK 2001. *The Practice of Nursing Research: Conduct, Critique and Utilization*. Philadelphia, PA: WB Saunders Company.
- Cáceres 2007. Digital Poverty: Concept and Measurement, with an Application to Peru, Roxana Barrantes Cáceres* Working Paper #337. From <<https://kellogg.nd.edu/publications/.../WPS/337.pdf>> (Retrieved on 28 May 2012).
- Castells M 2002. *The Internet Galaxy*. Oxford: Oxford University Press.
- Cendrós G, Jesús, Luis Ugas 2007. The digital gap in Maracaibo City in Venezuela. *Telematics and Informatics*, 24: 41-47.

- Chen Y, Zhu J 2004. Measuring information technology's indirect impact on firm performance. *Information Technology and Management Journal*, 5(1-2): 9-22.
- Chinn MD, Robert WF 2007. The determinants of the global digital divide: A cross-country analysis of computer and internet penetration. *Oxford Economic Papers*, 59: 16-44.
- Demoussis M, Giannakopoulos N 2006. Facets of the digital divide in Europe: Determination and extent of internet use. *Economics of Innovation and New Technology*, 15(3): 235-246.
- DiMaggio P, Hargittai E, Neuman WR, Robinson JP 2001. Social implications of the Internet. *Annual Review of Sociology*, 27(1): 307-336.
- Dollar D, Kraay A 2000. Growth is Good for the Poor. Development Research Group. The World Bank. *Mimeo*.
- Fuchs C, Horak E 2008. Africa and the digital divide. *Telematics and Informatics*, 25: 99-116.
- Gebremichael MD, Meseret D, Jason WJ 2006. Bridging the gap in sub-Saharan Africa: A holistic look at information poverty and the region's digital divide. *Government Information Quarterly*, 23: 267-280.
- Gutiérrez LH, Gamboa LF 2008. *An Approximation to the Digital Divide Among Low Income People in Colombia, Mexico and Peru: Two Composite Indexes*. Documentos de Trabajo 39. Bogotá, Universidad del Rosario, Facultad de Economía, Colombia.
- Hargittai E 2003. The digital divide and what to do about it. In: DC Jones (Ed.): *New Economy Handbook*. San Diego, CA: Academic Press, pp. 821-839.
- Rehman S, Ramzy V 2004. Awareness and use of electronic information resources at the Health Science Centre of Kuwait University. *Library Review*, 53(3): 150-156.
- Rice RE, Katz JE 2003. Comparing internet and mobile phone usage: Digital divides of usage, adoption, and dropouts. *Telecommunications Policy*, 27: 597-623.
- Hong KS, Kuek MK, Ridzuan AA 2003. Students' attitudes toward the use of the Internet for learning: A study at a university in Malaysia. *Educational Technology and Society*, 6(2): 45-49.
- Kasushe M 2005. Bridging the digital divide in sub-Saharan Africa: The rural challenge in Uganda. *The International Information & Library Review*, 37(3): 147-158.
- Kebede G 2004. The information needs of end-users of Sub-Saharan Africa in the digital information environment. *The International Information and Library Review*, 36: 273-279.
- Luambano I, Nawe J 2004. Internet use by students of the University of Dar es Salaam. *Library Hi Tech News*, 21(10): 13.
- Makgetla NS 2004. Women and the Economy. From <<http://www.workinfo.com/Articles/gender3.htm>> (Retrieved on 28 May 2012).
- Mariscal J 2005. Digital divide in a developing country. *Telecommunications Policy*, 29: 409-428.
- Norris P 2001. *Digital Divide. Civic Engagement, Information Poverty, and the Internet Worldwide*. New York: Cambridge University Press.
- Ono H 2006. Digital inequality in East Asia: Evidence from Japan, South Korea, and Singapore. *Asian Economic Papers*, 4: 116-142.
- Ono H, Zavodny M 2007. Digital inequality: A five comparison using microdata. *Social Science Research*, 36: 1135-1155.
- Quibria MG, Shamsun NA, Ted T, Mari-Len R 2003. Digital divide: Determinants and policies with special reference to Asia. *Journal of Asian Economics*, 13: 811-825.
- Ravallion M 2000. Growth and Poverty: Making Sense of the Current Debate. *Mimeo*. Washington DC: The World Bank.
- Sachs J 2005. *The End of Poverty. How We Can Make it Happen in Our Lifetime*. London: Penguin Books.
- Siti R, Dawam M, Khairul AA, Kamaruzaman J, Taniza T, Shamsul JE, Suhardi WM 2009. The use of ICT in public and private institutions of higher learning, Malaysia. *Computer and Information Science*, 2(4): 122.
- Tinio V 2003. ICT in Education. From <<http://www.apdip.net/publications/iespprimers/ICTinEducation.pdf>> (Retrieved on 28 May 2012).
- Trieghaardt J 2006. Reflections on Poverty and Inequality in South Africa. Paper presented at the Annual Association of South African Social Work Education Institutions (ASASWEI) Conference, Organised by University of Venda Department of Social Work, 18-20 September. From <[http://www.dbsa.org/Research/Documents/Povertypercent20and percent20inequality percent20in percent20South percent20 Africa percent20Policy percent20 considerations percent20in percent20an percent20 emerging percent20 democracy.pdf](http://www.dbsa.org/Research/Documents/Povertypercent20and percent20inequality percent20in percent20South percent20Africa percent20Policy percent20 considerations percent20in percent20an percent20 emerging percent20 democracy.pdf)>. (Retrieved on 28 May 2012).
- Van Dijk J 2006. *The Network Society. Social Aspects of New Media*. 2nd Edition. London: SAGE.
- Vicente MR, Ana JL 2006a. A multivariate framework for the analysis of the digital divide: Evidence for the European Union-15. *Information and Management*, 43: 756-766.
- Vicente MR, Ana JL 2006b. Patterns of ICT diffusion across the European Union. *Economics Letters*, 93: 45-51.
- Williams NE, Adekannbi JB 2009. Factors influencing use of the Internet: A questionnaire survey of the students of University of Ibadan, Nigeria. *The Electronic Library*, 27(4): 718-734.
- Wilson EJ 2006. *The Information Revolution and Developing Countries*. Cambridge, MA: MIT Press.
- Zaidieh AJY 2012. The use of social networking in education: Challenges and opportunities. *World of Computer Science and Information Technology Journal (WCSIT)*, 2(1): 18-21.

Paper received for publication on September 2014

Paper accepted for publication on November 2016