

Algorithmic Prediction of Internet Technology Utilization in Learning

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Abstract— Internet technology has been revolutionary over the years especially in the educational sector. However, the utility of internet technology in the learning process of a student in a higher learning institution has not been determined over the years. This has been due to the evolution that has taken place in education.

This paper aims at helping in the development of an algorithmic model that will be used for the prediction of internet technology utilization in learning. Specifically, the research will focus on modelling the Cobb- Douglas production theorem to predict the learning output of a given student considering the utility of the internet technology, the infrastructural investment made by the institution of higher learning and the effort of the student.

The results of this ongoing research will eventually be of great importance in helping institutions of higher learning determine their returns after investing in internet technology. The students will also be informed on how to use the internet technology in a better way in order to get the best out of the resource.

Keywords — internet technology, internet utilization, Cobb Douglas theorem, predictive models, prediction algorithms

I. INTRODUCTION

Technology, as an application of scientific knowledge, has greatly assisted in building useful tools, growing different skills among people, and gathering all sorts of materials both in our daily lives and in our varied occupations since the start of human life. It involves the use of science in different ways and as a result, help in achieving a goal and coming up with solutions to varied problems [7].

This draws great advantage from knowing that digital technologies are now driving many current activities. Such digital technologies are being developed and applied in different forms, types and classes. Significantly, general advancement in digital technology has brought about major changes and advancement in communication. One advancement which has seen speed advances and development is the internet. The internet refers to one large international collection of intertwined communication and computer systems and channels which enable the exchange of data and information generated by these systems and passed on to

different users [8].

There is still lack of research on how to measure the utility derived from the utilization of internet resources in the learning environment; particularly its effect on the learners' outcome. This has made it difficult to tell whether internet technology assists in learning or does not assist in learning. It is also hard to tell whether institutions have invested enough as far as internet technology is concerned and whether the investment they have made is efficient enough for students to use the internet for learning purposes.

This paper discusses internet technology utilization in general, internet use in learning, predicting internet technology utilization and the predictive ability of algorithmic models.

II. INTERNET TECHNOLOGY UTILIZATION

The concept of utility has its origin in economics. Human beings base their actions and behaviors on the goodness and usefulness they obtain from a given good or service. Utility can also denote the contentment that an individual gets after using a good or a service or being in a given place [12]. The utility of technology is therefore the satisfaction one gets while interacting and using technology to build useful tools, growing different skills in people and gathering materials. As a result, this ends up in social economic development of society at large.

In this paper, the utility of internet technology will be viewed as a service and will be measured in proportionate terms since services can be useful to an individual and not useful to another [12].

The utility of internet technology in a learning environment will be considered from the point of usage and non-usage of technology, the people who use technology and benefits derived from the usage of technology in meeting the needs of the users and contributing to a certain level of development.

III. INTERNET USE IN LEARNING

The internet and its use in academia cannot be separated. However, access to the internet resource remains inequitable. This in-equitability affects students in higher learning institutions [9]. Nevertheless, this has not discouraged students

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from using the internet and as a result [10], internet cafés have provided a temporary solution to this.

Research has shown that students spend a lot of time online sourcing for academic materials than they do in the library. Research has shown that institutional infrastructure has had a hindrance due to inadequate investment by the institutions [11]. Lack of appropriate knowledge of the internet and appropriate internet usage skills affects the use of the technology.

Exploring the different factors that positively or negatively affect the usage of internet among students, two models can be applied. The technology acceptance model (TAM) posits that use of an application, a system or a technology is based on the user's perception: either how simple the technology is to use or how useful the technology is in solving a pending problem [1]. The task-technology fit (TTF) model suggests the possibility that information technology has a particular effect on the performance of different categories of people. If the information technology matches the tasks, user's performance will get better. The technology adoption model (TAM) looks at the student and the decisions they make to use or not to use a particular technology.

IV. PREDICTING INTERNET TECHNOLOGY UTILIZATION

In order to effectively predict internet technology utilization in a learning institution consider the cost of investing in internet technology, the level of internet technology knowledge and skills level in students, availability and accessibility of the internet technology infrastructure and the effort expended by the student in using internet technology [10] [11]. These factors will help in predicting how the internet resource is utilized in the learning process.

The learning output of the student while using internet technology can therefore be modeled to give the productivity of the student. This is dependent on the student's effort in using internet technology, the infrastructural investment required to provide internet services and the utilization of the internet technology. These attributes can be modeled using a production theorem like the Cobb-Douglas theorem.

The Cobb-Douglas theorem is used in the field of econometrics and can be fitted to a time series analysis. The Cobb-Douglas production theorem is defined as,

$$Q = a l^\alpha k^\beta \quad (1)$$

where Q is the total quantity of goods produced, a is a scaling parameter (this acts as a fixed regulator which checks on the increase/decrease of attributes and is not dependent on other attributes), l and k are factors of production represented as labour and capital investment respectively. In this study, labour is the learner effort and capital investment is the technological investment made by an institution. The sum of the exponents $\alpha + \beta$ determines the returns to scale on factor inputs (labour and capital).

In order to effectively apply the Cobb-Douglas theorem in modeling the learning outcome of a student who

decides to use or not to use internet technology, several functions will be applied. These functions will be used to measure the effort of a student, the infrastructural investment made by the institutions and the level of the utilization of internet technology by the student.

Combining these functions and substituting them on (1), we get

$$\begin{aligned} Y_t &= f(L_{(t)}, T_{(t)}) \\ &= a\gamma_t \cdot L_{(t)}^\alpha \cdot T_{(t)}^{1-\alpha} \cdot U(x) \end{aligned} \quad (2)$$

where the learning output Y_t is a composition of $L_{(t)}$ (labour (effort)) and $T_{(t)}$ (technological investment (infrastructural investment (hardware and software) for internet technology access and use), $U(x)$ is the additive multiple attribute utility of internet technology, a is a scaling parameter, γ is the influence of peers and family on the students rate of technical progress, α is the partial output to effort and t is the time used in task execution.

V. PREDICTIVE ABILITY OF ALGORITHMIC MODELS

Computers represent processes as algorithmic models. An algorithmic model is a set of carefully defined instructions that take a set of inputs, manipulate them, and produce some output. Computer programmers encode algorithms in software using programming languages as a sequence to execute instructions one at a time [2].

Predictive models come into existence whenever researchers use the collected data to simulate a modelling technique which will be used for prediction [3]. To build a predictive model one needs to assemble the dataset that will be used for training. Predictive analytics are helping companies and individuals all over the world to extract value from historical data obtained from day to day life [3].

In order to predict the internet technology utilization levels using an algorithmic model, there is need to measure the parameters that will aid in the development of the model. These parameters are utility of internet technology, mental effort and technological investment in higher learning institutions.

A. Utility of internet technology, $U(x)$

By using indicators, the two possibilities offered to the students can be defined. For instance, if the student uses internet technology, then the numerical value 1 is used and if the student does not use internet technology, then the numerical value 0 is used, that is,

$$U(x) = \begin{cases} 1 & \text{if student uses} \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

The student is thus in one of the two states, either in the state of "using internet" or "not using internet". From the indicator variables given in (3), the probability of being in the "using" state or the "non-using" state is given by the Bernoulli distribution (since this distribution only gives possibility of two outcomes, either Yes/No or Success/Failure):

$$B(p, q) \quad (4)$$

Where p represents the utilization of internet, that is, being in the state of using the internet and $q=1-p$ representing the state of not using the internet.

The student has two possible choices that can be taken as random events $(x_n \ n = 0, 1)$ with associated weights $(w_n \ n = 0, 1)$ and corresponding utility $(u_n(x_n))$. Hence, the utility of a single event, $U(x_n)$ would be a function of the weight of the attribute (w_n) and its own importance and relevance (utility) $(u_n(x_n))$.

$$U(x_n) = f[w_n u_n(x_n)] \quad (5)$$

Combining the single-attribute utilities, an aggregate utility index for each alternative can be obtained. Hence, the general form of the utility function that has n attributes is shown in (6).

$$\begin{aligned} U(x_1, x_2, \dots, x_n) &= f[w_1 u_1(x_1), w_2 u_2(x_2), \dots, w_n u_n(x_n)] \\ &= \sum_{i=1}^n w_i u_i(x_i) \end{aligned} \quad (6)$$

where u_i is the utility value of some attribute i , x_i is the input value of the attribute of interest and w_i is the weight assigned to attribute i .

B. Mental effort

The effort expended by a student can be equated to the time spent executing a task. Mental effort can be defined as the total capacity quantified and used in instructional demands [6]. Mental effort also refers to the total cost accumulated by an individual to achieve optimum performance [10]. In order to understand how learning takes place, the amount of effort expended by a student needs to be established. An appropriate function that can be considered in measuring the effort of a student is the Logistic Testing-Effort Function (TEF) [13].

The Logistic Testing-Effort Function (TEF) describes a scenario in software development where effort is measured as a pattern and can therefore be applied and used in measuring the students effort while using internet technology in learning [13]. This function was used instead of the Weibull-type TEF to test the effort expended in a software development scenario. Logistic TEF gives a well-defined resource usage curve in a given distinct project over a defined time period.

The cumulative effort consumed over time $(0, t]$ equals

$$W(t) = \frac{N}{1 + A \cdot \exp(-\alpha \cdot t)} \quad (7)$$

where $W(t)$ is cumulative effort, N is the testing-effort used, A is a constant parameter in the logistic TEF, α is the rate of testing-effort used and t is time.

Substituting and using the function to consider the effort expended by a student, $L(t)$ can denote the total effort used and this can be modeled can be modeled using the logistic TEF given by

$$L(t) = \frac{N}{1 + A \cdot \exp(-\alpha \cdot t)} \quad (8)$$

where $L(t)$ is cumulative effort, N is the testing-effort used, A is a constant parameter in the logistic TEF which will represent the knowledge level of a student, α is the learning rate of the student who uses internet technology and t is time.

N represents the knowledge level of the student while A represents the control variables.

Knowledge is not a visible asset and it is never considered as an important aspect since it can't be represented as a capital asset or as a financial asset. Nevertheless, knowledge refers to the capacity to act [4] and as a result make an important distinction between different individuals and their behavior. The knowledge level of a student can be measured by the self-efficacy/capability of the student in using internet and the attitude of the student while using the internet.

Self-efficacy refers to the different ideologies that people hold regarding their capabilities with reference to their performance on different levels and on different events. These beliefs influence the feelings, thoughts, motivations and behaviors of individuals [17]. The self-efficacy of a student includes their feelings towards the internet, their thoughts on the usefulness of the internet and their general behavior towards the internet.

Attitude refers to an expression of like or dislike towards a place, thing, event or a person [16]. An attitude can be formed from a person's past and present based on their exposure to different situations in life. The attitude of the student towards internet technology considers what the student likes and dislikes as far as using internet technology in learning is concerned. This will help measure whether the student has the right attitude towards internet technology or not.

Therefore, N , the knowledge level of the student can be measured as a factor of two inputs:

$$N = f(N_{SE} \ N_A) \quad (9)$$

Where N is the knowledge level of student, N_{SE} is the self-efficacy/capability of the student in using internet technology and N_A is the attitude of the student towards internet technology.

The control variable A in (8) can be measured using two parameters, the university physical environment and the personality of the student. These two factors will be constant and will most likely remain unchanged during the course of the research.

The university physical environment includes checking on what is available in the different universities for the provision of internet connectivity. This includes checking on the nature of the available lecture theatres as well as labs and availability of internet connectivity in the universities.

Personality refers to differences in behavior, thoughts and feelings of an individual which ends up affecting how they

socialize and react to different environments [15]. These differences also affect how one understands an individual as a whole. The student personality in this case looks at the different behaviors of students while using the internet as a learning resource and how they cope with the challenges that they face as they use the internet resource.

Therefore, A , the control variable will be measured as a factor of two inputs:

$$A = f(A_{EN} S_{PE}) \quad (10)$$

Where A is the control variable, A_{EN} is the university physical environment and S_{PE} is the student personality.

C. Technological investment in institutions of higher learning

Higher institutions of learning are required to invest in and implement a technology of their own choice. This technology directly affects the internet utilization levels in the institution. However, the most important aspect of the technology does not rely on the infrastructure in place but the cumulative resources needed to use internet technology (efficiency) and how these resources affect learning.

The efficiency of the internet technology can be captured as a parameter, in such a way that a higher value of the parameter implies a more efficient technology [14].

Two symbols are used to refer to the technology efficiency and the technology itself. The efficiency derived by an institution in using a given technology at a certain time t , $t \geq 0$, can be represented as $\zeta(t)$.

The cumulative efficiency of the most efficient technology derived from the particular technology at time t , $t \geq 0$, can be represented as $\theta(t)$. Of course, it must hold that, $0 \leq \zeta(t) \leq \theta(t)$, for any $t \geq 0$ [24].

An institutions profit flow when it produces with technology ζ , $\zeta \geq 0$, equals $\pi(\zeta)$, where π is an increasing function of ζ . For instance, a firm whose production function is

$$h(v, \zeta) = \zeta v^a \quad (11)$$

where $v (\geq 0)$ is a variable input, $\zeta (\geq 0)$ is the efficiency parameter, and $a \in (0, 1)$ is the constant output elasticity.

Further, assuming that the output price and the input price are fixed and equal to p and q , respectively, then the profit flow for the firm equals

$$\pi(\zeta) = \max_v (p \zeta v^a - qv) \quad (12)$$

where $\pi(\zeta)$ is the profit flow of the firm with a given technological investment, d and g are the output and the input price of the technological investment respectively, ζ is the technology efficiency parameter, v is a variable input and a is the constant output elasticity.

Adopting (12) and using it in an institution of higher learning, the profit flow of an institution of higher learning with a given technological investment $T(t)$, will be given by

$$T(t) = \max_v (p \zeta v^a - qv) \quad (13)$$

Where $T(t)$ is the profit flow of the institution with a given technological investment, p and q are the output and the input price of the technological investment respectively, ζ is the technology efficiency parameter, v is a variable input and a is the constant output elasticity.

VI. CONCLUSION

As mentioned above, internet technology significantly helps students in higher learning institutions in the learning process, to fulfil their academic and social needs and increase their well-being. In order to measure the learning output of a student who uses internet technology, there is need to examine and model the different factors highlighted in this paper. This research is still ongoing and the instruments for measuring the different parameters are being worked on. Once the parameters are measured, they will be used in the Cobb Douglas production theorem which will give an index to represent the learning output of the student.

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REFERENCES

- [1] F. D. Davis, "Perceived usefulness, perceived ease of use and user acceptance of information technology.," *MIS Quarterly*, vol. 13, no. 3, pp. 319-340, 1989.
- [2] S. H. VanderLeest and J. Nyhoff, "Being fluent and faithful in a digital world," in *Algorithmic Modeling*, N. Zylstra, Ed., Calvin College, 2005.
- [3] A. Guazzelli, Predicting the future Part 2: Predictive modeling techniques, Zementis: IBM Inc, 2012.
- [4] K. Sveiby, The New Organizational Wealth: Managing and Measuring Knowledge-based Assets, San Francisco, CA: Berret-Koehler, 1997.
- [5] S. G. Hart and L. E. Staveland, "Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research.," in *Human mental workload*, P. A. Hancock and N. Meshkati, Eds., Amsterdam, Elsevier Science, 1988, pp. 139-178.
- [6] F. Paas, "Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive load approach," *Journal of Educational Psychology*, vol. 84, pp. 429-434, 1992.
- [7] "National Centre for Research Resources," 2013. [Online]. Available: <http://science.education.nih.gov/supplements/nih4/technology/guide>. [Accessed November 2013].

- [8] "Russian Federation," 2012. [Online]. [Accessed November 2013].
- [9] J. S. Peters and M. O. Okon, "Students' perception of causes and effects of examination malpractice in the Nigerian educational system: The way forward for quality education.," *Procedia-Social and Behavioral Sciences*, vol. 114, pp. 125-129, 2014.
- [10] C. Anunobi and A. Ogbonna, "Web 2.0 use by librarians in a state in Nigeria," *Developing Country Studies*, vol. 2, no. 5, pp. 7-66, 2013.
- [11] O. Osunade and O. Ojo, "Library and internet usage: a case study of the University of Ibadan," *The Information Technologist*, vol. 3, no. 2, pp. 19-29, 2012.
- [12] "Hybrid Learning: Theory and Practice," in *7th International conference*, Shanghai, China, 2014.
- [13] BusinessDictionary, 2015. [Online]. Available: <http://www.businessdictionary.com/definition/utility.html>. [Accessed December 2015].
- [14] F. N. Parr, "An alternative to the Rayleigh curve for software development effort.," *IEEE Transactions Software Engineering*, SE-6, pp. 291-296, 1980.
- [15] K. Huisman, *Technology Investment: A game theoretic real options approach.*, Tilburg: Tilburg University Press, 2000.
- [16] APA, *American Psychological Association*. [Online] Available at: <http://www.apa.org/topics/personality/>. Accessed 18th January 2017, 2017.
- [17] G. Allport, Attitudes. In: C. Murchison, ed. *A Handbook of Social Psychology*. Worcester, MA: Clark University Press, p. 789-844, 1935.
- [18] A. Bandura, Self-efficacy. *Encyclopedia of human behavior*, Volume 4, p. 71-81, 1994.