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Mining Students' Data to Analyse Usage Patterns in eLearning Systems of Secondary Schools in Tanzania

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Abstract: The adoption and use of various eLearning systems to enhance the quality of education in secondary schools in Tanzania is becoming common. However, there is little evidence to suggest that students actually use them. Existing studies tend to focus on investigating students' attitude towards using these systems through surveys. Nonetheless, data from surveys is normally subject to the possibility of distortion, low reliability, and rarely indicate the causal effects. This study adopted WEKA and KEEL as data mining tools to analyze students' usage patterns and trends using 68,827 individual records from the log file of the Halostudy system implemented in secondary schools in Tanzania. The study found that the system usage is moderate and in decline. There is also variability in the usage of multimedia elements with biology having the highest number while mathematics has the lowest. Students from Dar es Salaam, Mwanza, and Arusha, in that order, had the highest system usage with the lowest being from the peripheral regions. The possible challenges limiting system usage are discussed. These findings show that data mining tools can be used to indicate usage patterns of systems implemented in sub-Saharan Africa and to help educators to find ways of maximising systems usage.

Keywords: educational data mining, learning analytics, eLearning systems, eLearning secondary schools.

Introduction

The adoption and use of various eLearning systems, such as Moodle, Sakai, and Blackboard, to improve the quality of teaching and learning at various levels of education in sub-Saharan Africa is becoming common (Ssekakubo, Suleman, & Marsden, 2011; Unwin et al., 2010; Venter, Rensburg, & Davis, 2012). In Tanzania, for instance, more than 50% of surveyed institutions were found to have installed eLearning systems of various kinds (Mtebe & Raisamo, 2014). In the beginning, the majority of these systems were implemented within higher learning institutions. In recent years, many of these systems have increasingly been implemented in secondary schools. Some good examples of eLearning systems implemented in secondary schools in Tanzania include the Tans-eL system (Kalinga, Bagile, & Trojer, 2006), Retooling system (Mtebe, Kibga, Mwambela, & Kissaka, 2015), Christian Social Services Commission system (CSSC, 2014), Shule direct system (Mtebe & Kissaka, 2015), and Brain share system (Mwakisole, Kissaka, & Mtebe, 2018).

With the increased number of students, which stretches beyond the limit of available teachers and learning resources, these initiatives aim to provide digital content accessible via the Internet where students can use these resources to enhance their learning activities. The majority of these initiatives aim to provide quality digital content to students with minimum intervention from teachers. For instance, the Shuledirect system has digital content for various subjects such as Physics, Chemistry,

Biology, English, Geography, Civics, Mathematics and Kiswahili (ShuleDirect, 2019). The Tans-eL system has digital content for Mathematics, Biology, and Chemistry (Kalinga et al., 2006).

Despite the continued investment in these systems, there is little evidence to suggest students across the country actually use them. These systems cannot help students improve learning if they are not used. Many studies have strongly shown that there is a correlation between eLearning system usage and students' performance (Filippidi, Tselios, & Komis, 2010; Jo, Kim, & Yoon, 2014) and students' satisfaction (Naveh, Tubin, & Pliskin, 2012; Tarigan, 2011). Despite these benefits, the lack of actual usage or underuse of systems implemented in sub-Saharan Africa is a common problem (Ssekakubo et al., 2011; Unwin et al., 2010), and has been a major setback against their success (Bervell & Umar, 2018; Lwoga, 2014). The need to ensure that students make full use of these systems is important so that the anticipated benefits are attained.

Many of the existing studies have focused on students' attitude towards using these systems through surveys (Mselle & Kondo, 2013; Msoka, Mtebe, Kissaka, & Kalinga, 2015). The findings from the majority of these studies tend to indicate students have positive attitudes but when it comes to actual usage their attitudes are more reserved. Moreover, data from surveys is normally subject to the possibility of distortion and low reliability and rarely indicate the causal effects (Jo et al., 2014). Therefore, there is a need for more sophisticated means for investing how students use these systems, which is important to avoid inefficient investments and ensure maximum utilisation of the installed systems.

Recently, data mining technologies have been making a lot of headway in capturing and analysing massive amounts of data generated by these systems (Romero, Ventura, & García, 2008). The eLearning system keeps a record of all the activities that students perform in the log files which can be analyzed and used to provide immediate feedback to educators (Romero, Espejo, Zafra, Romero, & Ventura, 2013). Despite these great potential benefits of data mining technologies, few studies have utilised them in investigating eLearning system usage amongst students in secondary schools in sub-Saharan Africa and Tanzania, in particular.

This study utilised data from a Halostudy system (https://halostudy.ac.tz/) log to investigate students' usage patterns in the system implemented in secondary schools in Tanzania. The Halostudy system was customised from the Moodle system to suit the context of secondary education. The study adopted WEKA and KEEL as data mining tools, involving 68,827 individual records, accessed the system for nearly 14 months. The findings from this study show that data mining tools can be used to indicate usage patterns of systems implemented in sub-Saharan Africa and help educators to find ways of maximising systems usage. The description of the Halostudy system is explained next.

The Halostudy System

The implementation of the Halostudy system can be traced back to 2013 when the Ministry of Education and Vocational Training (MoEVT) of the government of Tanzania implemented the retooling project in collaboration with the College of Information and Communication Technologies (Mtebe, Kibga, et al., 2015). The retooling project in this context was a project aimed at reskilling or upgrading subject content knowledge of teachers in science and mathematics subjects in secondary schools in Tanzania. Generally, the project aimed at addressing the low success rates of students in science and mathematics subjects in secondary schools through enhancing teachers' subject content

knowledge of the subjects they teach. It was claimed that the failure rates of students in these subjects were linked to inadequate secondary school teachers' knowledge on the subjects.

To address this problem, under the retooling project, the multimedia enhanced digital content (in the form of animations, simulations, video, and audio) were developed and shared with teachers across the country via the customised Moodle system. The developed content was for only topics perceived to be difficult to understand for an assessment conducted in various regions in Tanzania. A total of 70 topics and 147 subtopics were developed and extensively supported with multimedia elements. More specifically, 93 videos were recorded, 57 animations were developed, and 201 still pictures were captured and integrated into the digital content (Mtebe, Kibga, et al., 2015). The developed multimedia enhanced content was then pilot tested with 2,000 teachers in 858 schools located in 13 regions in Tanzania. During the pilot phase, the developed multimedia enhanced content was uploaded into the customised Moodle system where teachers accessed the system for three months before conducting a follow-up study using SMS quizzes. The result showed that multimedia enhanced content helped to improve subject content knowledge of teachers who participated in the retooling project (Mtebe, Kondoro, Kissaka, & Kibga, 2015). In a separate study, the customised Moodle system was perceived to be easy to use by the majority of surveyed teachers (Mtebe, Mbwilo, & Kissaka, 2016). More details about the retooling project can be obtained in Mtebe, Kibga, et al., 2015.

Building from the success of the retooling project, the College of Information and Communication Technologies (CoICT) in partnership with Viettel Tanzania Ltd, aka Halotel, developed an Internet based application with multimedia enhanced content drawn from the retooling project for all topics of science and mathematics subjects for secondary education in Tanzania. While the retooling project focused on enhancing teachers' subject content knowledge of the subjects they teach, this project focused on students. This is because the content developed during the retooling project could be used by students to enhance their subject content knowledge as this was the same content used by the teachers.

In order to disseminate the content and ensure that many students benefit from it, the College entered into an agreement with Halotel to use its network to facilitate dissemination of the content to the learners in secondary schools in Tanzania. The Halotel has connected 427 secondary schools with the Internet, which could potentially benefit from the developed content. The content was made free of charge to the students who had access to the Internet through www.halostudy.ac.tz. Moreover, the Halostudy app was also developed for those who have mobile devices and is available at the GooglePlay Store. Figure 1 shows an interface of the Halostudy platform.

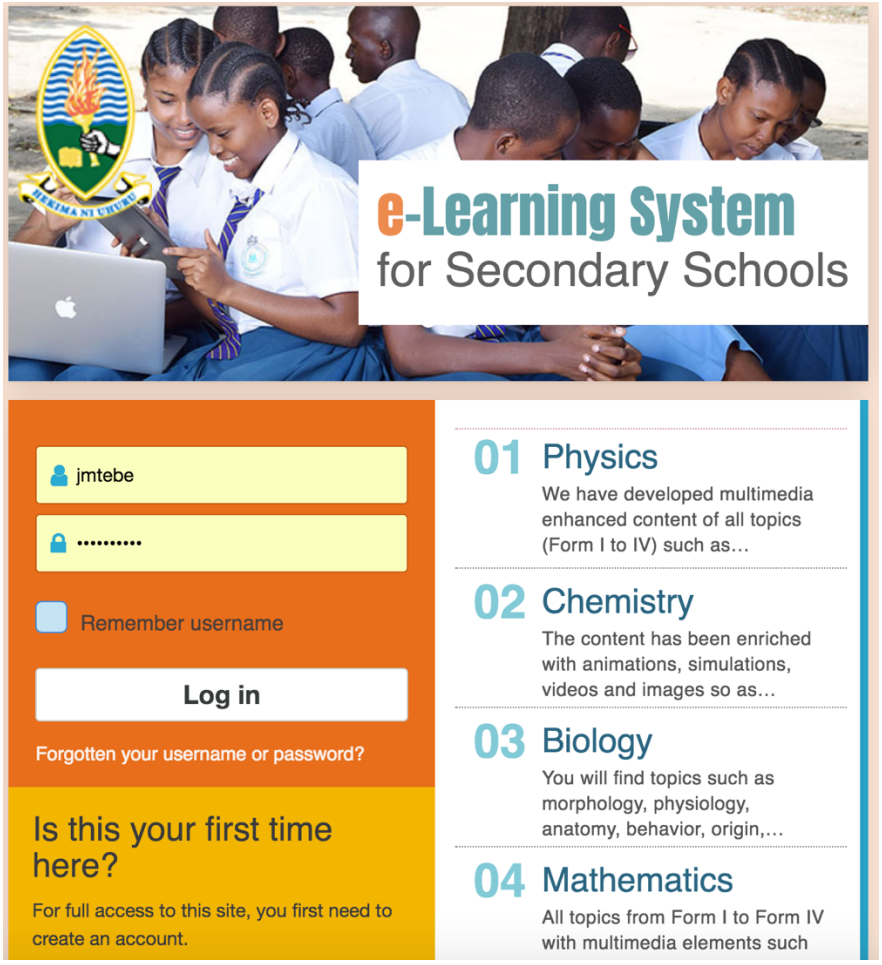

Figure 1: The interface of the Halostudy system. (Source: https://halostudy.ac.tz/)

Since the launching of Halostudy in August 2017, students all over the country have been accessing the content to enhance the content knowledge of their subjects. Just like other similar initiatives, the Halostudy system was meant to facilitate students' centered learning; whereby students could access and use the multimedia enhanced content anywhere, anytime, without interaction with teachers. Similarly, teachers could also use the content to enhance their subject content knowledge for complementing classroom environments. Despite the continuous use of the Halostudy system throughout secondary schools in Tanzania, little information on how students use the system and what features are mostly used was available. In this study, we utilised data from a system log to investigate students' usage patterns in the Halostudy system using WEKA and KEEL as data mining tools.

Related Works

The eLearning systems tend to keep records of all the activities that students have performed in the form of a log file. The activities which are kept in the log file include the time, Internet Protocol address, name of the student, the action completed, and the activities performed in different modules (Kadoic & Oreski, 2018). Due to the large quantities of data these systems can generate daily, it is very

difficult for educators to manage them manually (Estacio & Raga, 2017; Romero et al., 2008).The data mining tools have adapted and been used to explore the unique types of data from eLearning systems to better understand how students learn and identify the settings in which they learn to improve educational outcomes (Romero & Ventura, 2013).

Given these advantages, studies have been using these mining tools to investigate systems features that have an influence on improving students' learning performance. For instance, Macfadyen and Dawson (2010) used data mining tools to analyse students data from a Blackboard system. Authors extracted the total number of discussion messages posted, the total number of mail messages sent, and the total number of assessments completed as key variables. Through regression analysis with the final grade, it was found that the variables explained more than 30% of the variation in student final grade.

Similarly, Mwalumbwe and Mtebe (2017) extracted data from the Moodle log of two courses delivered at the Mbeya University of Science and Technology, using a developed mining tool and subjected into linear regression analysis with students' final results. The study found that discussion posts, peer interaction, and exercises were determined to be significant factors for students' academic achievement in blended learning. However, time spent in the system, number of downloads, and login frequency were found to have no significant impact on students' learning performance.

Kadoic and Oreski (2018) used Moodle plugins to extract data from the log file and analyse students' behavior at the Faculty of Organization and Informatics at the University of Zagreb. The results of the students' behavior were interpreted in a bid to improve students' learning. Similarly, Romero et al (2013) extracted data from Moodle logs and used them to predict student performance. Generally, the study found that the regular usage of features such as assignments, quizzes, and forum activity had an impact on students' final grade.

In general, these studies and many others, such as those in Estacio and Raga (2017); Hung and Zhang (2008); Kotsiantis, Tselios, Filippidi, and Komis (2013); Lotsari, Verykios, and Panagiotakopoulos (2014); Podgorelec and Kuhar (2011); Wen and Rose (2014); Yu and Jo (2014); and Zorrilla, García, and Álvarez (2010), have successfully used data mining tools to predict students' performance based on log data from learning environments. Very few studies applied data mining tools to analyse log data to provide informed feedback on how students use eLearning systems in secondary schools in Tanzania. In a review of 74 articles, published between 2007 and 2017, Mtebe and Raphael (2018) found that the majority of articles focused on users' attitude and perceptions towards using these systems. With increased adoption and use of these systems in secondary schools in Tanzania, the use of data mining tools that will use log data to inform educators on the usage pattern is increasingly important.

Methodology

Research Design

This study is focused on investigating the access pattern of students using the eLearning system. We were interested in understanding how the system was being used and by whom. To find this out, we started by investigating the level of access based on the identified variables as shown in Table 1.

Table 1: Variables Extracted for the Study

No.	Variable	Description
1.	Course Name	Identification string of the course in which the action is related. This variable helped to differentiate between various courses accessed in the system
2.	Source of Access	This data enabled to identify the region/places where users accessed the system
3.	Type of Content	The system has text, video, animations, and simulations as types of content. This variable aimed to find out to what extent users have been using various types of the content installed in the system.
4.	Time	Date and time stamp of when the action was executed which enabled to estimate the geographical location of users when they accessed the system.
5.	IP Address	Unique numerical label assigned to the device used by the user in order to determine the type of the device used when accessing the system.
6.	Action	Type of action initiated which enabled to determine the number of most and least active users used the system. This number was later grouped per months.

Using variables in Table 1, we were able to get a general picture on the behavioral pattern of students who used the system. To do so, usage data was extracted from the Halostudy system implemented in secondary schools in Tanzania in the form of text-based logs. These logs are a record of time-based events that occur in the system. Every time a user performs a certain action, information about it is recorded in the logs. The recorded data contains attributes with variables shown in Table 1. The data was extracted from the time the system was launched in August 2017 to the time that this study was conducted (September 2018) and exported to a CSV file. The extracted file had a total of 68,827 individual records of raw data before being further analysed using data mining tools. The data mining tools used to analyse the obtained data are explained next.

Data Mining Tools and Data Analysis

The Halostudy is based on the Moodle platform and therefore the data mining tools compatible with Moodle system were selected and adopted. Therefore, Waikato Environment for Knowledge Analysis (WEKA) and Knowledge Extraction based on Evolutionary Learning (KEEL) data mining tools were adopted in extracting data from the Halostudy system in the form of text-based logs. The WEKA (https://www.cs.waikato.ac.nz/~ml/weka/index.html) is a an open source software, written in Java, aiming at allowing users to compare different machine learning methods on new data sets (Hall et al., 2009). It consists of visualisation tools and algorithms for data analysis and predictive modeling, together with a graphical user interface for easy access to these functions (Holmes, Donkin, & Witten, 1994).

The KEEL tool (http://www.keel.es/) is also an open source software that supports data management and the design of experiments. The KEEL pays attention to the implementation of evolutionary learning and soft computing based techniques for data mining problems including regression, classification, clustering, pattern mining and so on (Ernández, Uengo, & Errac, 2011). The WEKA and KEEL tools were selected due to the fact that they are both open source tools, developed in Java, and use the same dataset external representation format (ARFF files). The CSV file was exported into the WEKA in order to generate some patterns based on the identified variables in Table 1. In areas where

the WEKA tool had limitations in generating the intended variables, the KEEL tool was used. The data from WEKA and KEEL tools were exported to Microsoft Excel for analysis with variables being grouped in the form of tables, charts and graphs for easy understanding.

Ethical Issues

This study used data mining tools to extract data from the Halostudy system in order to understand usage patterns amongst users from the onset of the project. However, like many other data mining studies, the issues of security, privacy, and individuality of data need to be respected and protected to make sure that people are judged and treated fairly (van Wel & Royakkers, 2004). In this study, the extracted data were treated confidentially by ensuring that the identified variables that might identify users were excluded. The excluded information included login credentials, personal user profiles, and personal details from quizzes, and the user's data in discussion activities.

Findings

Access per Subject

The level of user activity for each subject was determined by comparing the access percentage of each subject. Therefore, the total number of records for each subject was expressed as the percentage ratio of the total number of records in the whole file. Of the 68,827 individual records, there was a small difference in access levels across the four subjects with biology having the highest number of accesses (19,960) equivalent to 29% compared to other subjects. Chemistry and physics had the lowest with 23% each as shown in Figure 2.

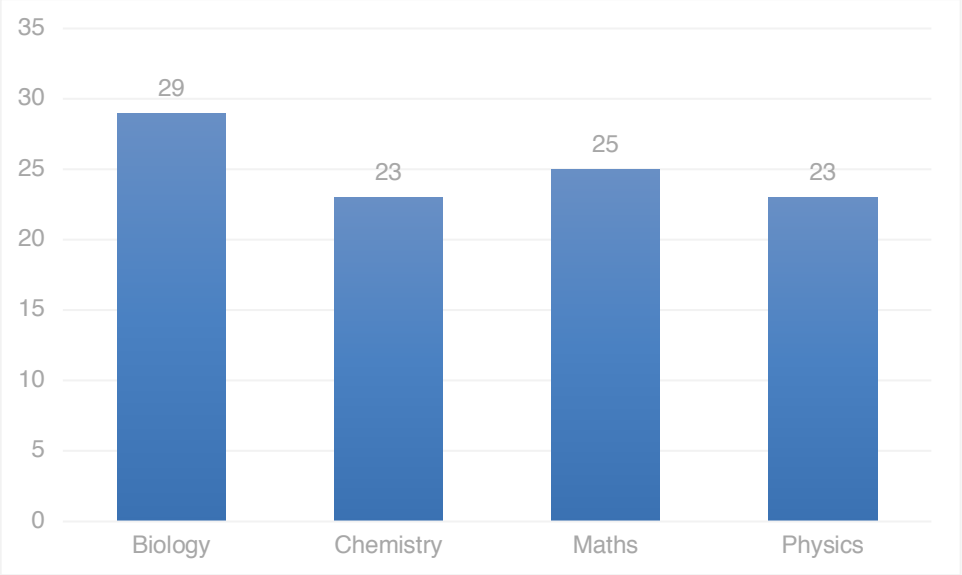

Figure 2: The percentage of users' access per subject.

In Tanzania's education system, students are allowed to drop chemistry and physics subjects at Form II if they are going into arts streams, while biology and mathematics are normally compulsory subjects. Therefore, those who accessed biology are likely the same students who accessed mathematics. On the other hand, the low percentage in chemistry and physics could be due to the fact that some students who dropped these subjects at Form II did not access them in subsequent classes, making a slightly small difference in access percentages.

Number of Users per Range of Access

The activity patterns in terms of numbers of most and least active users were analysed. Users were categorised into different groups depending on the number of times they accessed the system while filtering records with duplicate users. Each group had an access range of 100, starting from 0-100, 100-200, and so on. The study shows that the majority of users accessed the system between 0-100 times followed by 102 to 201 times. Few users accessed the system 1400 times plus in the studied period. Figure 3 shows the number of users per range of access for the studied period.

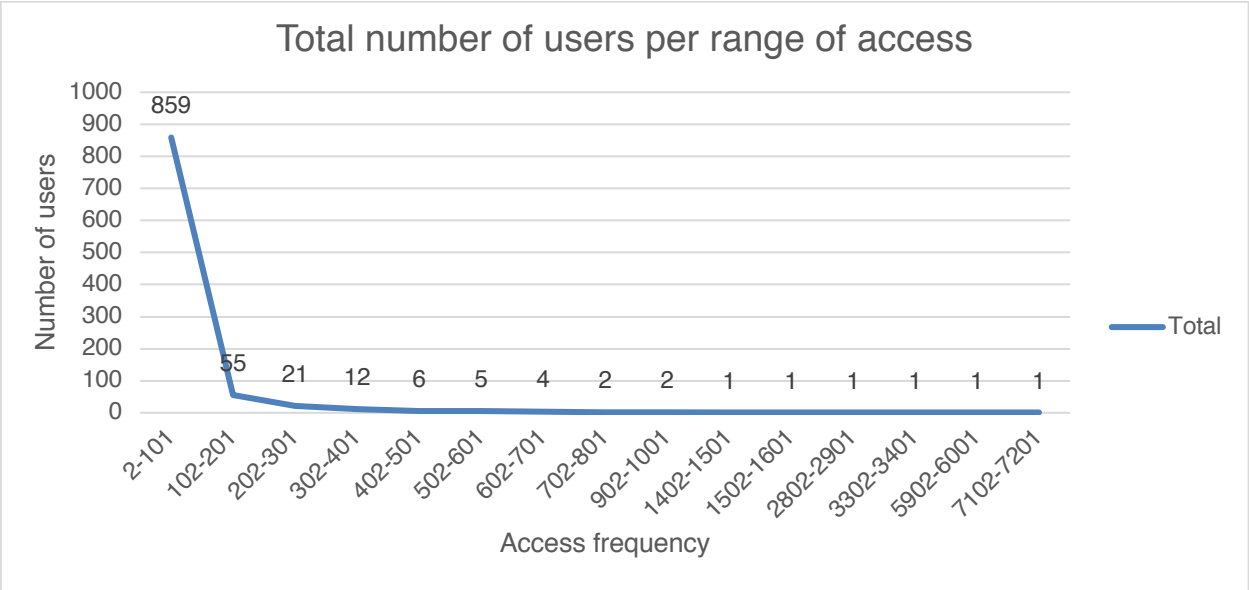

Figure 3: The number of users per range of access in the Halostudy system.

The study has shown that the access levels of students is moderate, with the majority of students accessing the system in a range starting from 0-100 in nearly 14 months. Clearly, despite 68,827 individual records available in the system, the majority of students do not access the Halostudy regularly. There are many reasons which could have contributed to this irregularity of Halostudy access, some of which are discussed in the challenges section in this study.

Multimedia Access per Subject

The multimedia content such as audio, video, and animations play a key role in the learning process. They are thought to enhance the understanding of abstract and difficult concepts that cannot be easily grasped from words alone (Steinke, Huk, & Floto, 2003). Moreover, they are thought to support students with different learning styles by presenting content in a variety of multimedia (video, audio and sound) (Woodcock, Burns, Mount, Newman, & Gaura, 2005). As shown in Figure 4, there is variability in the usage of multimedia elements, with biology having the highest number (more than 1500 times) while mathematics has the lowest.

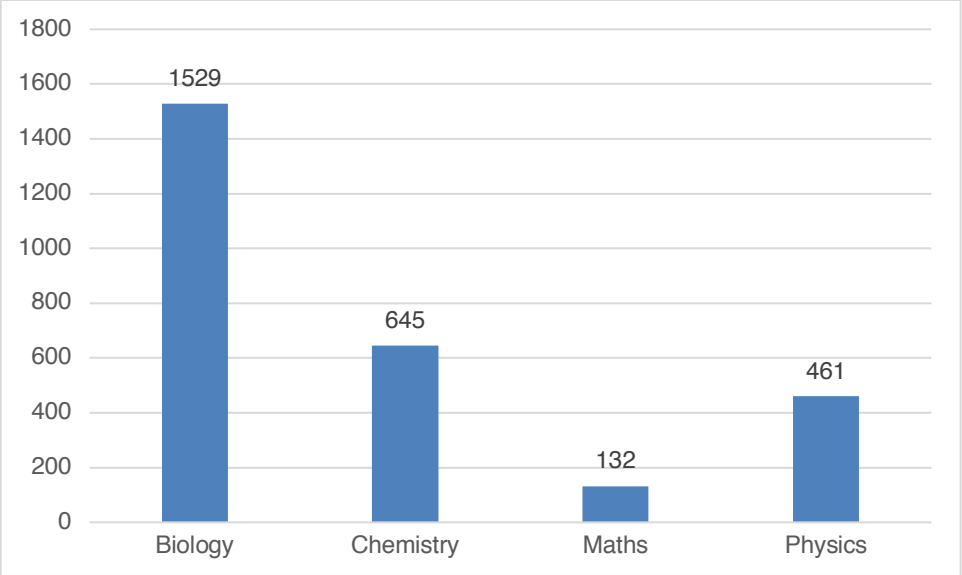

Figure 4: The number of users per multimedia access per subject.

Multimedia Access per Subject per Form

The access of multimedia elements was also grouped per year of study from Form I to Form IV, in order to determine which cohort had accessed mostly the multimedia elements. The study shows that Form II and Form III students had the highest access of multimedia elements throughout the three subjects (see Figure 5). Interestingly, only a few Form IV students accessed multimedia elements nearly 100 times.

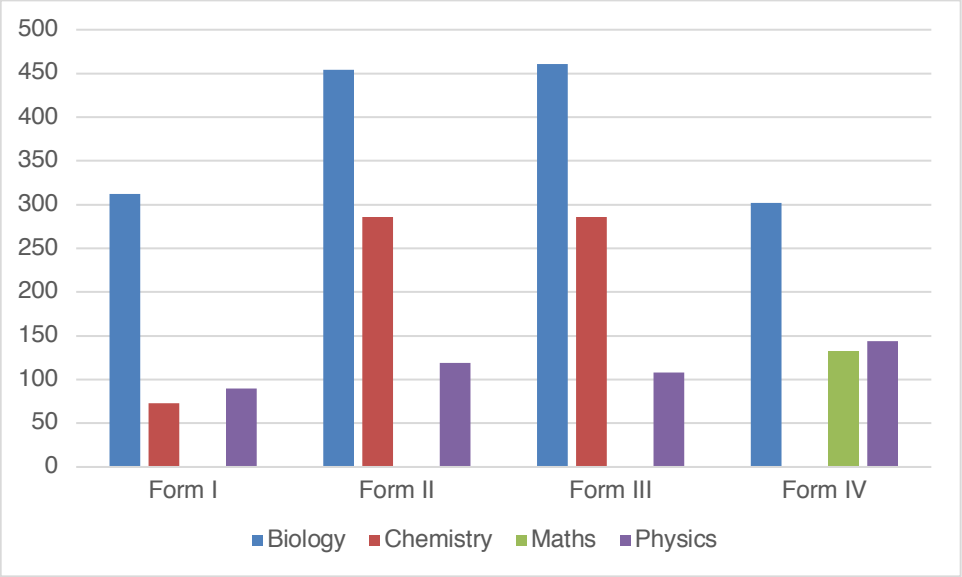

Figure 5: The number of users per multimedia access per class of study.

Access per Month

The level of user engagement can change over time depending on various factors. The access frequency per month starting from when the system was launched were extracted and analysed. The results show that the most users accessed the system in the month of January 2018, followed by November 2017. However, the trend shows that the number of users accessing the system has been decreasing towards the end of September 2018. In fact, August 2018 and September 2018 had the lowest number of users who accessed the system as shown in Figure 6.

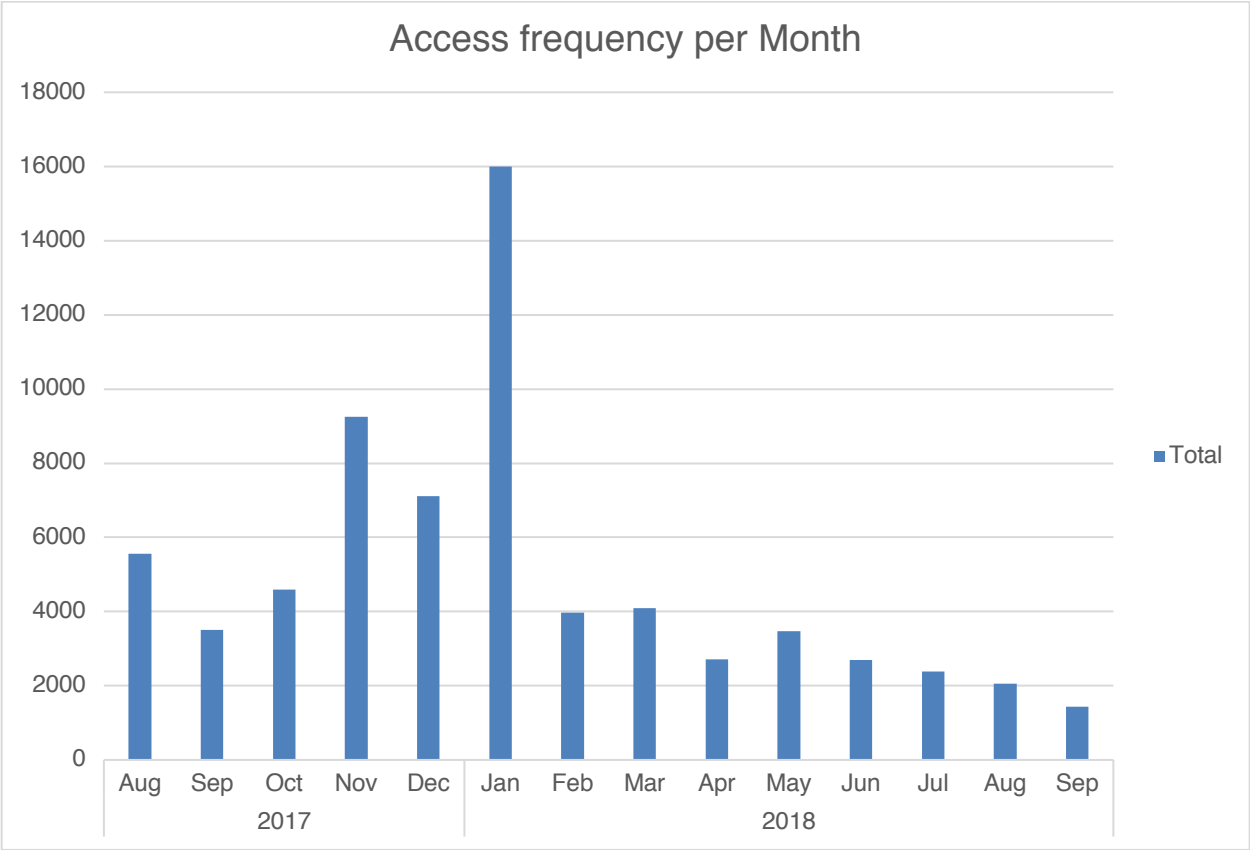

Figure 6: The number of users accessed the system per month.

The trend indicates that many students tend to access the system between November and December. This finding could be due to the fact that that many students tend access the system close to the final exams. Final year exams are normally conducted between November and early December in the majority of secondary schools in Tanzania. Another possible explanation could be that students tend to have access to the Internet during the holidays and outside school premises (Mwakisole et al., 2018). The majority of students are normally in holidays in December and January each year in the Tanzanian education system.

Web vs Mobile app Access

The system's mobile version was also developed to provide access to those with access to mobile phones. Therefore, we were interested to find out the media that students used the most when accessing the system. Interestingly, 71.7% of students accessed the system using the web while 28.3%

of students accessed the system via mobile app. This result may be explained by the fact that the use of mobile phones are strictly prohibited in many secondary schools in Tanzania (Kafyulilo, 2014; Kihwele & Bali, 2013) despite many students having access to them (Chambo, Laizer, Nkansah-Gyekye, & Ndume, 2013; Malero, Ismail, & Manyilizu, 2015; Mwakisole et al., 2018; Tarimo & Kavishe, 2017). Therefore, the use of mobile phones could not make much difference in helping students to access the system.

Access per Location

Users were also categorised on geographical location in order to visualise the accessibility and usage of the system across the country. Therefore, the total number of records originating from each region was calculated. Generally, an IP address value was used to estimate the geographical location while the IPInfo (IPinfo, 2018) was used to convert IP addresses to specific regions. Figure 7 shows the distribution of the percentage of users accessing the system per region.

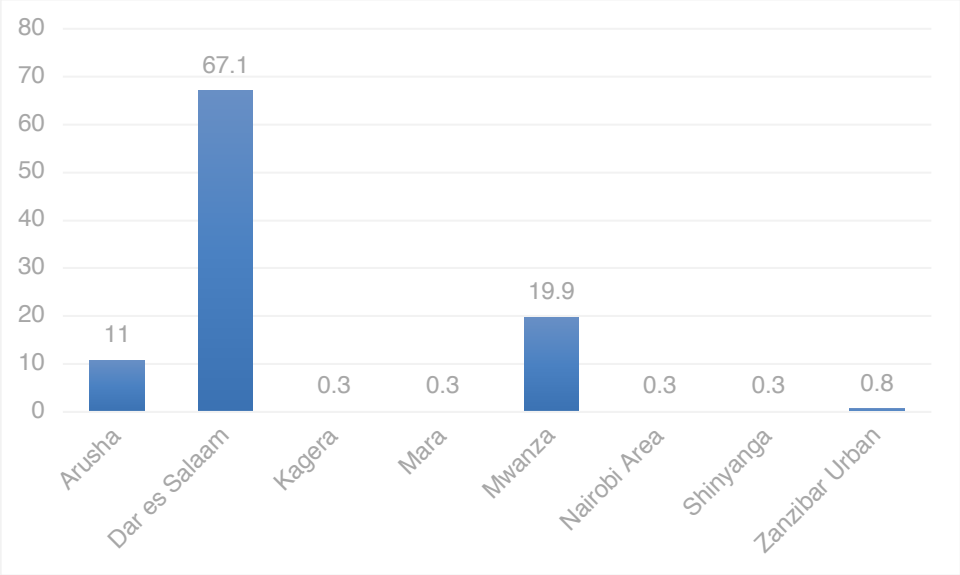

Figure 7: The percentage of users accessing the system per region.

The findings show that many students who accessed the the system are from big cities with good Internet connectivity — Dar es Salaam, Mwanza, and Arusha, in that order. The lowest accessed regions were those located in peripheral areas such as Kagera, Mara, and Shinyanga. This finding confirms the fact that access to reliable Internet in rural areas is still a problem. The government has been making considerable efforts to roll out fiber optical cable, including the East African Submarine Cable System, SEACOM, and the East African Marine System, in order to widen access to the Internet in the rural areas (Mtebe & Raphael, 2018). It seems, therefore, these initiatives have not benefited many users in rural areas.

Possible Challenges Limiting Access to the Halostudy System

The study has shown that the students' access of the Halostudy system is moderate, with the majority of students having accessed the system in a range starting from 0-100 in nearly 14 months. It was also interesting to note that many students tend to access the system during the holiday months. Some of

the possible challenges that could have hindered the access and use of Halostudy system are as follows:

Lack of Computers in Schools

The government and its partners have been making considerable efforts towards equipping schools with computers and other ICT facilities. Recently, the government equipped approximately 31.4% of government secondary schools (out of 3,601) with computers ranging from 1 to 68 computers, with 20.1% them being connected to the Internet (MoEST, 2017). Similarly, Halotel supported 400 schools and the Tigo firm supported 700 schools with computers connected to the Internet in selected regions of the country (Kazoka, 2016; Tanzania TELECOMS, 2016). Despite these efforts, and many others, many secondary schools in Tanzania do not have computers (Muhoza, Tedre, Aghaee, & Hansson, 2014) which limits students from accessing the system. It should be noted that the Halostudy is an Internet based system and therefore schools need to have computers connected to the Internet.

The Cost of Internet Connectivity

The cost of Internet remains a major challenge to the access of eLearning systems in Tanzania. The cost of connecting 300 computers was estimated to be 4 million TShs (2140€ ≈ 3100$) per month for a dedicated 704kb/128kb satellite connection (Tedre, Ngumbuke, & Kemppainen, 2010). This is definitely unaffordable to many secondary schools in Tanzania, given the fact that they depend on government funds to run most of their services. Although use of the mobile Internet could be a solution to the majority of schools, the cost of Internet bundles provided by many mobile firms is still high (Mtebe & Raphael, 2018). For instance, the subscription of 10GB of Internet cost around US$ 25 per month, which is expensive to the majority of students. In a study conducted in seven schools in Dar es Salaam, it was found that the majority of students were paying less than Tsh 1000/ = (US $ 0.5) for the Internet per week via their mobile devices. Despite the availability of special student bundles (1GB per week @ Tsh 1500 [0.6 USD]), many students cannot afford them (Ghasia, De Smet, Machumu, & Musabila, 2018).

Attitudes on the Use of Mobile Phones

Studies have shown that mobile phones can compensate for a lack of existing infrastructure and erratic Internet connections in sub-Saharan Africa and Tanzania, in particular (Chambo et al., 2013; Ghasia et al., 2018; Joyce-Gibbons et al., 2018). However, teachers' and parents' negative perceptions and attitudes towards students using mobile phones in schools continues to be a limiting factor. Teachers and parents believe that mobile phones have a detrimental effect on student performance and moral values (Kihwele & Bali, 2013) and that students tend to misuse them by watching pornographic and entertainment materials instead of studying (Kafyulilo, 2014). Therefore, while it might be possible for students to access these devices informally, they cannot bring them to school or use them regularly at home limiting the possibilities of using them for accessing eLearning systems.

Inadequate ICT Skills

The use of Halostudy requires students to have the skills of using computers and the Internet. Nonetheless, many students do not have adequate skills to use ICT facilities and the Internet, especially in rural areas (Barakabitze, Kitindi, Sanga, Kibirige, & Makwinya, 2015; Tedre et al., 2010). The low number of students who accessed the system could be partly due to the lack of ICT and Internet skills amongst students in Tanzania.

Lack of Awareness of the System

Another challenge that could have limited students' access to the system is lack of awareness among students of the existence of the system. The college and Halotel mobile firm have been advertising this system via social media and some selected radios in Tanzania. Due to the large population size of students and limited advertisement budgets, it is unlikely that many students are aware of this system.

Conclusion

The adopting and use of eLearning systems in enhancing the quality of teaching and learning at various levels of education in Africa will continue to increase given the proliferation of mobile phones and the Internet. With these systems continuing to generate massive amounts of new data through the data log, it is important to help educators with tools that will help them to understand the status of students' learning and finding ways of helping struggling students. The use of data mining tools can effectively utilise existing generated data in eLearning systems to provide feedback for instructors about the efficiency of education such as the quality of students' postings, visualisation usage behaviors, and engagement levels.

This study aimed to demonstrate how the existing data mining tools can be used to provide important information about students' access in the system implemented in secondary schools in sub-Saharan Africa. To do so, the study utilised data from a Halostudy system log to investigate students' usage patterns in the system implemented in secondary schools in Tanzania using WEKA and KEEL as data mining tools. Using a total of 68,827 individual records accessed in nearly 14 moths, the study was able to generate useful usage patterns that can help educators to make informed decisions in finding strategies that will maximise system usage.

Generally, the usage of the system has been moderate and has been declining almost every month. Declining usage is an important indication that the anticipated benefits may not be realised. These findings call for immediate action in order to find ways of ensuring that users use the system. The findings of this study have shown that data mining tools can be used to show usage patterns of systems implemented in sub-Saharan Africa through the use of system log data. However, one notable weakness of this study is that the quantitative data do not provide explanations of such trends and patterns. For instance, reasons for multimedia access per subject were high for biology compared to other subjects that could not be revealed. A mixed study would have been appropriate in complementing the findings obtained from the quantitative data. A further study with more focus on qualitative data is therefore recommended.

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