Integration of Mobile Intelligent Tutoring Systems in Teaching Mathematics

Ratemo Makiya Cyprian

Kisii University

---***---

Abstract: *Mathematics plays a critical role in driving economies and scientific transformation of any society. However, students' poor performance over the years in secondary schools' national examinations remains a major concern to all the stakeholders. The poor performance has been attributed to high influx of students due to free secondary school programme posing a challenge of inadequate one-on-one tutoring leading to attitude issue. The proposed Mobile Intelligent Tutoring Systems (M-ITS) have the potential to deliver cheap and one-to-one support to students outside the traditional classrooms and computer laboratory settings. The use of mobile devices can be an advantage with most schools with inadequate financial resources to invest in and maintain modern computer laboratories since the cost of acquisition and maintaining light weight mobile devices is lower. In addition, learners can easily carry them between home and school as well as share the mobile tutors between classes in the same school. This paper outlines the use of Mobile Intelligent Tutoring Systems in supporting the Mathematics human tutors in secondary schools and the role that mobile devices can play in disseminating and supporting the knowledge gained by intelligent tutors. The paper reviewed the existing related literature and traditional architecture of ITS. It then proposed an additional model on mood detector to be included in the design of M-ITS. The final part of the paper makes considerations on the development and implementation of Mobile Intelligent Tutoring Systems.*

Keywords*: Computer-Based Instruction, Intelligent Tutoring Systems, Mobile device, Mobile Intelligent Tutoring Systems.*

Introduction

Mathematics subject has been lauded as a subject that is crucial not only to everyday life processes like budgeting but also in career development and technological advancement. However, studies have shown that the performance of Mathematics has over the years continued to be poor nationally as a result of lack of enough tutoring, amongst other factors more so with the influx of students due to free primary and secondary education (KNEC, 2015)

An intelligent tutoring system (ITS) is a computer system, containing an artificial intelligence component, that aims to provide instant and personalised instruction or feedback to learners without requiring intervention from a human teacher (Russel & Norvig, 1995). The software tracks student's work, tailoring feedback and hints along the way and by collecting information on a particular student's performance, the software can make inferences about strengths and weaknesses, and can suggest additional work (Al-Nakhal & Naser, 2017).

ITS aims to duplicate the proven benefits of one-to-one tutoring, in cases where students would otherwise have accessed to one-to-many instruction from a single teacher such as classroom lectures or no teacher at all such as online homework. ITSs are often designed with the goal of providing access to high quality education to each and every student

An ITS can be used to enable the students work independently, to improve their understanding of concepts within related domain, and to take progress of problem-solving ability for each of them (Martin, 2001). ITS can be able to assist not only the students but also the teachers in developing and managing courses (Shin et al., 2006).

The wide use of cell phones in society has led researchers to investigate methods to employ mobile devices in education (Al-Nakhal & Naser, 2017) hence the concept of Mobile Intelligent Tutoring System (M-ITS). According to Communications Authority of Kenya (CAK), as at 30th September 2018, the number of active mobile subscriptions in the country stood at 46.6 million attributed to the fact that most users own more than one SIM card either from the same or different service providers. The number is projected to go up following plummeting costs of acquiring and maintaining smart phones.

According to Brown (2015) and Kam et al. (2009), mobile device has been argued to be an appropriate tool for educational delivery in developing countries. The argument behind this is that mobile device is low-power device that can be used in places without electricity. Although mobile device such as cell phone is largely purchased for voice communications, it is also able to run educational software that support visuals and voiceovers (Kumar, 2009). Most of all, the cell phone is the fastest growing technology platform in the developing countries like Kenya.

The use of mobile devices can be an advantage with most schools with inadequate financial resources to invest in and maintain modern computer laboratories since the cost of acquisition and maintaining light weight mobile devices is lower. In addition, learners can easily carry them between home and school as well as share the mobile tutors between classes in the same school.

For the purpose of this paper, the term "mobile device" comprises standard cell phones, smart phones (those utilizing an operating system providing voice services as well as additional data processing applications), and personal digital assistants (PDAs) - providing data processing without voice capabilities. Whereas laptop computers are portable, users interact with them in ways that are more similar to desktop computers than they do with smaller devices. Thus, it does not fall under 'mobile device' category.

Table 1.1 Comparisons of Desktop and Mobile Tutoring Systems

Description	Desktop	Mobile Device
Interface	Full size keyboard Multi-window design	Small Keyboard Single-window design
Display	14+ inch display	2-5 inch display
Connectivity	Ethernet, Wi-Fi	Wi-Fi, Cellular
Delivery	Standalone	Client only
Usage	Classrooms and computer labs	Anywhere and anytime

Problem Statement

Mathematics plays a critical role in driving economies and scientific transformation of any society. It is a vehicle that is envisaged to move Kenya's economy to industrial rank by 2030. However, students' poor performance over the years in secondary schools' national examinations remains a major concern to all the stakeholders.

Much has been done and said with aims of improving performance with little success including introduction of "Strengthening of Mathematics and Science in Secondary Education (SMASSE) Project", launched in Kenya in 1998 with an aim of improving mathematics and science education through In-service Training (INSET) for teachers (Nancy and Alice, 2007). Amongst the factors that contribute to poor performance is inadequate remedial or follow-up tutoring in most schools which has been compounded further by the influx of students due to free primary and secondary education.

There has been unprecedented enrollment in Secondary schools since the introduction of free primary and secondary education straining the existing human resource with the current teacher to student ratio being very high creating very little time for follow-up tutoring thus the need for a complement. On the other hand, there has been increased penetration of mobile devices with capabilities to support different learning software. The Kenyan government has also endeavoured to improve electricity coverage across the Country. According to Kenya Power and Lighting Company, the electricity access rate in the country stood at 73.42% as at the end of April 2018, owing to various national electrification projects that have been undertaken by Kenya Power such as the Last Mile Connectivity Project and Global Partnership and Output-Based Aid (GPOBA) that targets informal settlements in urban areas and low-income households in the rural areas. With the introduction of Digital Literacy Program (DLP), it is a stepping stone for development of tutoring applications.

Related Work

In early 1970s, few researchers defined a new goal for computer-based instruction. They adopted the human tutor as their educational model and sought to apply artificial intelligence techniques to realize this model in "intelligent" computer- based instruction.

Personal human tutors provide a highly efficient learning environment (Cohen and Kulik, 1982) and have been estimated to increase mean achievement outcomes by as much as two Intelligent Tutoring Systems standard deviations (Bloom, 1984). The goal of ITSs would be to engage the students in sustained reasoning activity and to interact with the student based on a deep understanding of the students' behavior.

From 1990s, research on pedagogy in the mathematics recognized that students learn mathematics more effectively, if the traditional learning of formulas and procedures is supplemented with the possibility to explore a broad range of problems and problem situations through ITS (Schoenfeld, 1990). In particular, the international comparative study of mathematics teaching (Baumert et al., 1997), has shown that teaching with an orientation towards active problem-solving yields better learning results since the acquired knowledge is more readily available and applicable especially in new contexts and that a reflection about the problem-solving activities and methods yields a deeper understanding and better performance.

According to James and Sowmya (2007), Carnegie Learning developed a suite of ITS based "cognitive tutors" in secondary-level mathematics. The systems, based on earlier research carried out by John Anderson and Ken Koedinger at Carnegie Mellon University, were tested in selected secondary school and students showed 50- to 100-percent improvement in problem solving and use of equations, tables, and graphs.

Erica and Jorg (2003) developed ActiveMath ITS used in problem solving, rule-based systems, knowledge representation, user modeling, adaptive systems and adaptive hyper-media, and diagnosis.

ALEKS (Assessment and Learning in Knowledge Spaces) is an online ITS aimed at tutoring Geometry and Business Mathematics courses (Anderson et al., 1996). It is web based and thus requires Internet connection for it to be accessed.

MathITS (Korhan, 2006) is an Intelligent Tutoring System for mathematics education at undergraduate and graduate level and employs the conceptual map modeling technique (Hwang, 2003). It is a student-centered system, which supports interactive learning.

Naser (2012) presented a Desktop Intelligent Tutoring System which was used to assist Grade Ten learners under Linear Programming. The students reported a positive mean score in the topic as a result of the system. Al-Nakhal & Naser (2017) developed an Intelligent Tutoring System for learning Computer Theory which was presented in the European Academic Research Conference. It was necessitated by poor performance of students in the topic which registered an improvement as a result of introduction of desktop based ITS. However, the architecture for the existing ITS are not suitable for mobile devices

Nour & Samy (2017) in their research presented an English and Arabic version of desktop intelligent tutoring system for teaching Mathematics that helped students understand the basics in areas such as algebra, addition and subtraction, polynomials, real numbers and roots of real numbers. The system was subjected to a focus group of students and the results was reported to be encouraging though it was only accessible while within school precincts.

Brown et al (2015) proposed a generic architecture for the Design of a Mobile Intelligent Tutoring System. They reviewed three aspects of mobile intelligent tutors — namely the interface, learning and teaching strategies. The system did not however consider emotions of the learners which has been proven to greatly impact the performance of Mathematics.

Mobile Intelligent Tutoring System

According to Brown (2015), Mobile ITSs have not received extensive research. There has been little research aimed at identifying how to adapt the desktop tutors and which aspects of the tutor to change, as aspects of desktop tutors require modification for mobile device content delivery.

The delivery of ITSs on mobile devices in Kenya has the potential to provide the significant advantages of intelligent tutoring systems to a wider audience of learners thus helping in bridging the digital divide.

Some secondary schools provide Internet and computer access to students but a deeper assessment reveals that the presence of technology does not equate to effective use of the technology (Yong et al., 2006). Among the several factors hindering use is the high student-to-computer ratio in schools. For those schools with computers, it is reported that no school has one computer for each student with the lowest computer-to-student ratio being approximately 3-to-1 (Christopher et al., 2007). On the other hand, nearly all students can access the mobile phones making it possible for schools to make use of handheld computing to coordinate technology use between home and school for the students. This trend is also pinpointing of the potential that mobile and handheld devices have to deliver a one-to-one computing solution to the education community (Quinn, 2000).

By using mobile devices, schools without the financial resources to invest and maintain large computer labs can have the ability to provide learners with ITS technology. One remarkable merit is that students can easily carry the tutors between home and school besides sharing the mobile ITSs between students in the same school thus enabling 'everywhere' and 'anytime' learning (Facer et al., 2015). The portability of mobile ITSs extends tutor use to outside of computer labs and traditional classrooms, thereby providing flexible learning opportunities to students at home, after school, and in other locations (Vahey et al., 2004). With the advancement of mobile device technology, there is also the possibility for mobile ITSs to execute as standalone applications, as opposed to client-server network based, thereby eliminating the need for an Internet connection, either wired or wireless.

According to the research conducted by Brown (2009) to determine whether mobile intelligent tutoring system provide learning gains greater than standard instructional activities, it was found out that students using the tutoring condition did experience an increase in post-test performance greater than students that did not use the tutor (using paper and pencil). As a result, it can be concluded that a mobile ITS can provide learning gains greater than standard instruction.

Mobile Intelligent Tutoring Systems Architecture

The traditional ITS architectures as proposed by Nwana (1990); Brown et al (2015); Erica & Jorg (2015); Nour & Samy (2017); Kalita & Ali (2018) had five modules: domain, student, expert, instruction and user interface models. This model forms the basis for the paper and the proposed M-ITS.

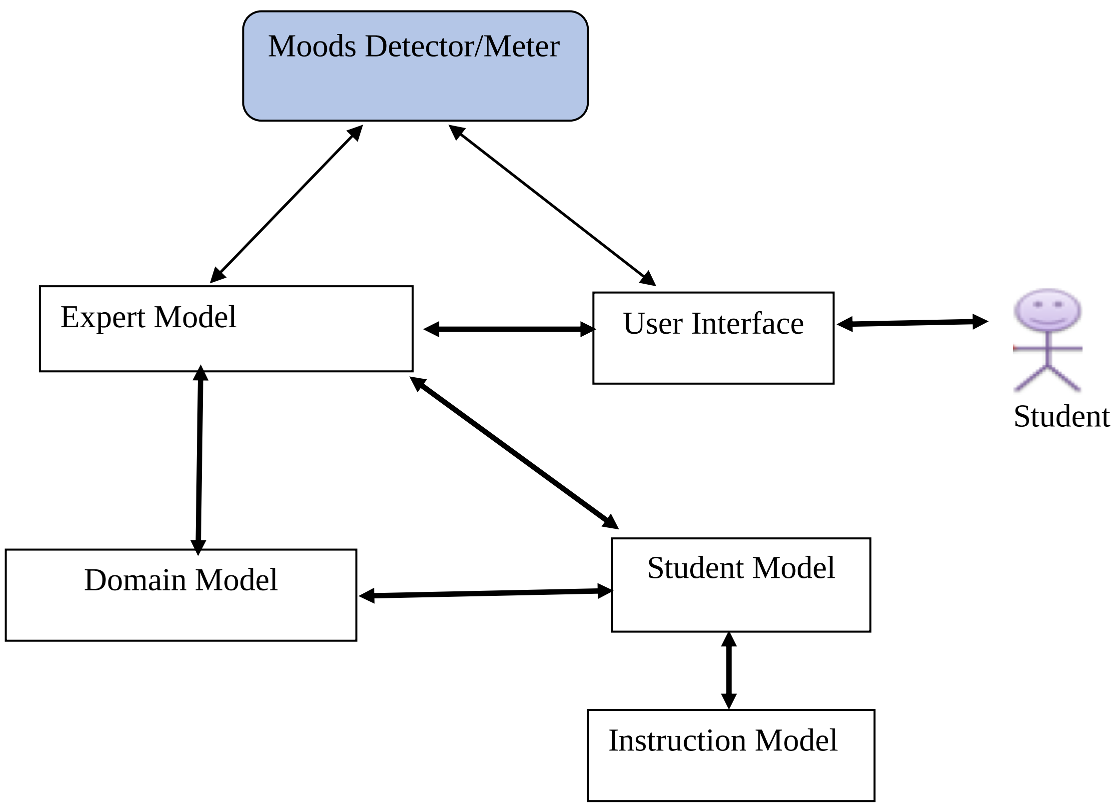

Figure 1: Intelligent Tutoring System Model

The first component is an expert model representing subject matter expertise. This knowledge comprises the understanding of the subject matter that an expert has in the tutored area i.e. expert model simply represents the expert knowledge and the ability to solve problems within a domain. The expert model accepts information from the domain and student models and makes choices about tutoring strategies and actions (Kalita & Ali, 2018). At any point in the problem-solving process the learner may request guidance on what to do next, relative to their current location in the model. In addition, the system recognizes when the learner has deviated from the production rules of the model and provides timely feedback for the learner, resulting in a shorter period of time to reach proficiency with the targeted skills.

The second component is the student model. This model represents the knowledge, skills, behaviour and other attributes of a student learning the domain. This model lets the ITS know who it's teaching (James et al., 2007) and tries to determine student's mental states. This module generates the student model with all information about the individual learner. It provides the information such that what the student knows or does not know, any misconceptions, degree of forgetfulness, reasoning skills, etc. (Korhan, 2006). It is considered as the core component of an ITS paying special attention to student's cognitive and affective states and their evolution as the learning process advances.

The third component is the instruction model, which is responsible for recognizing student input and responding to student actions i.e. enables the ITS to know how to teach, by encoding instructional strategies used by the tutoring system (Kalita & Ali, 2018). The instructor model selects the most appropriate instructional intervention based on the knowledge of a learner's strengths and weaknesses, skills, expertise levels, and student learning styles. In addition, the instructor model may also choose topics, simulations, and examples that address the student's competence gaps. It is also known as pedagogical or tutor module (Martin, 2001)

The domain model which is also known as the cognitive model is built on a theory of learning which tries to take into account all the possible steps required to solve a problem. More specifically, this model contains the concepts, rules, and problem-solving strategies of the domain to be learned. It can fulfill several roles: as a source of expert knowledge, a standard for evaluating the student's performance or for detecting errors (Nkambou et al., 2010).

The instruction model is responsible for recognizing student input and responding to student actions. The instructor model selects the most appropriate instructional intervention based on the knowledge of a learner's strengths and weaknesses, skills, expertise levels, and student learning styles. In addition, the instructor model may also choose topics, simulations, and examples that address the student's competence gaps. It is also known as pedagogical or tutor module (Nour & Samy, 2017))

The fifth component is the user interface, an essential module that provides the means by which the user can communicate with the system. It is the integration of the models that separate ITS technology from other forms of computer-aided instruction (Heffernan et al., 2003).

The paper proposes an intelligent moods meter/detector to be incorporated. Mathematics performance is determined by the mood of the student/learner that directly affect concentration in solving a problem. Research has shown that happiness has a positive effect on learning, memory and social behavior. Conversely, negative emotional states, such as anger and sadness, have been shown to have a negative impact on learning and motivation. According to Chai et al (2017), emotions have substantial influence on the cognitive processes in human beings which can include perception, attention, learning, memory, reasoning, and problem solving. It is argued that emotion has a particularly strong influence on attention which modulates the selectivity of attention as well as motivating action and behavior. This attentional and executive control is intimately linked to learning processes, as intrinsically limited attentional capacities are better focused on relevant information (Jack & Schyns, 2015).

Considerations for Developing Mobile ITS Applications for Mathematics Tutoring

The current educational system produces lesson plans, learning activities, and assessments based upon traditional educational models. However, the introduction of mobile devices enables students to interact and collaborate with one another in ways not realized before. Therefore, instructors must determine how to design lessons and activities structured around this mobility and accurately quantify the results of the use of the technology.

The use of mobile devices also raises questions that relate to the implementation of the technology, namely the hardware and software. Previous trials of mobile learning applications reveal that concerns regarding device ownership, battery life, and network connectivity can greatly affect the learning outcomes of students (Facer et al., 2015). Understanding of these issues could then provide information to inform the design of the applications themselves. For instance, knowing that students may not have stable internet connections may force the designer to create a standalone application or one that requires periodic synchronization for it to function properly.

The Ministry of Education should also have universal legislation or policy governing delivery of content in Schools and in particular owning of mobile devices

There is further need to consider the trade-offs of functionality versus costs of proprietary and open source software.

As much as mobile learning applications can be transformative, it is very important to understand and consider the existing learning environment in which it is intended.

Representation of diagrams and limited amount of text poses another challenge. As a result, the instructors should decide on which content could best be presented in mobile device. The diagrammatical representation is limited by screen size.

Conclusion

Mobile ITS implementation has great potential to help improve Mathematics performance in Kenyan Secondary schools with modification of traditional architecture to include mood detector model. However, certain research issues such as its development, legislation issues, interface, teaching and learning strategies and architecture (hardware and software) should be addressed in order to realize the full benefits of mobile ITS. By so doing, Kenya will boast of m-Learning and thus will reach more students and help to bridge the digital divide. However, the successful use of Mobile Intelligent Tutoring Systems in teaching mathematics will need a well-defined and focused leadership as well as determined effort to bring about the desired change.

References

[1] Anderson, J.R., Reder, L.M., and Simon, H.A. (1996), Situated Learning and Education. Educational Researcher Vol 25 No 4, pp 5-11.
[2] Al-Nakhal MA; Naser SSA. An Intelligent Tutoring System for learning Computer Theory. European Academic Research. 2017, 4(10).
[3] Baumert J., Lehmann R., Lehrke, M., Schmitz, B., Clausen M., Hosenfeld I., K¨oller O., and Neubrand J. (1997), Mathematisch-naturwissenschaftlicher Unterricht im internationalen Vergleich. Leske und Budrich
[4] Bloom, S. B. (1984), The 2-sigma problem: The search for methods of group instruction as effective as one-to one- tutoring, Educational Researcher, Vol. 13, pp. 4-16
[5] Brown Q. (2009), Mobile Intelligent Tutoring System: Moving Intelligent Tutoring Systems Off The Desktop. Ph.D.Thesis, Drexel University
[6] Brown, H. T. (2015), The role of m-learning in the future of elearning in Africa, ICDE World Conference.
[7] Castells, M. (1999), Information Technology, Globalization, and Social Development, United Nations Research Institute for Social Development
[8] Chai M. Tyng, Hafeez U. Amin, Mohamad N. M. Saad, and Aamir S. Malik (2017). The Influences of Emotion on Learning and Memory. Front Psychol. 8: 1454.
[9] Erica, M. and Jorg, S., ActiveMath: An Intelligent Tutoring System for Mathematics, German Research Institute for Artificial Intelligence (DFKI)
[10] Facer, K., Faux, F., and McFarlane, A. (2015), Challenges and Opportunities: Making Mobile Learning a Reality in Schools: 4th World Conference on m-Learning.
[11] Heffernan, N., Koedinger, K. R. and Aleven V. (2003), Tools towards Reducing the Costs of Designing, Building, and Testing Cognitive Models, Proceedings of Behavior Representation in Modeling and Simulation, BRIMS
[12] Nwana, H. S (1990). Intelligent tutoring systems: an overview: Artificial Intelligence Review. 4(4), pp. 251–277
[13] James, O., Sowmya, R. (2007), Intelligent Tutoring Systems: Using AI to Improve Training Performance and ROI
[14] Jack R. E., Schyns P. G. (2015). The human face as a dynamic tool for social communication. Curr. Biol. 25 621–634
[15] Kalita, J., Ali, A. (2017). Intelligent Tutoring Systems: A Comprehensive Historical Survey with Recent Developments. University of Colorado Colorado Springs, USA
[16] Kam, M., Kumar, A., Jain, S., Mathur, A., and Canny, J. (2009), Improving literacy in rural India: Cellphone games in an after school program. Proceedings of IEEE/ACM Conference on ICTD
[17] Kenya National Examination Council (KNEC) (2015). 2010 - 2014 KCSE Reports. Vol 1. Nairobi: KNEC
[18] Koedinger, K. R., Anderson, J. R., Hadley, W. H., and Mark, M. A. (2015). Intelligent tutoring goes to school in the big city. International Journal of Artificial Intelligence in Education, Vol 8, pp 30-43
[19] Martin, B.I. (2001), Intelligent Tutoring Systems: The Practical Implementation of Constraint-based Modeling. Ph.D. thesis, University of Canterbury.
[20] Mitrovic, A., Martin, B., Suraweera, P. (2017), Constraint-based tutors: past, present and future. IEEE Intelligent Systems, special issue on Intelligent Educational Systems, vol. 22, no. 4, pp. 38-45
[21] Nancy, W. N. and Alice, N. W. (2007), SMASSE project, Tsukuba Journal of Educational Study in Mathematics, Vol.25, pp. 4-7
[22] Naser SSA. (2012) A Qualitative Study of LP-ITS: Linear Programming Intelligent Tutoring System. International Journal of Computer Science & Information Technology. 4(1):209-220.

[23] Nkambou, R., Bourdeau, J., and R. Mizoguchi, R. (2010). Modeling the domain: An introduction to the expert module," in Advances in Intelligent Tutoring Systems. Springer Berlin Heidelberg, 308 (1), 15–32
[24] Quinn C. (2000), m-Learning: Mobile, Wireless, In-Your-Pocket Learning. Available: http://www.linezine.com/2.1/features/cqmmwiyp.htm (Last accessed March 30, 2010).
[25] Russel, S., and Norvig, P. (1995), Artificial Intelligence: a modern approach. Prentice Hall.
[26] Schoenfeld, A.H.(1990), A Source Book for College Mathematics Teaching. Mathematical Association of America, Washington, DC
[27] Shin N., Norris C. and Soloway E. (2006), Effects of Handheld Games on Students Learning in Mathematics, Proceedings of the 7th International Conference on Learning Sciences, pp. 702-708.
[28] Vahey, P., Tater, D., and Roschelle J. (2004), Leveraging Handhelds to Increase Student Learning: Engaging Middle School Students with the Mathematics of Change, Proceedings of 6th International Conference on Learning Sciences
[29] Yong, Z, Kenneth A. F., and Nicole C. E., Fostering Meaningful Technology and Learning with Technology: Characteristics of Effective Professional Development. Information Technology Journal, Scialert. 2006; 7(3):528-532.

About the Authors

Mr. Charles Koech

Charles C. Koech is a PhD student pursuing PhD in IT at Jomo Kenyatta University of Science and Technology. He has Msc. Information and bachelor's degree in Computer Science & Engineering. He has passion for research in Mobile Technology, Expert Systems (AI), Digital Signal Processing, Big Data Analytics, Blockchain, Internet of Things (IoT), Geographical Information Systems and Enterprise Resource Planning Systems.