An ontology-based framework for mobile learning in rural secondary schools

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In some countries mobile learning is becoming an important issue in academic institutions, as teachers and students get connected to networks through smart phones that combine telephony, computing, messaging and multimedia. However, in rural areas the process of designing, communicating and presenting learning resources, content services and learning content for mobile learners poses challenges. Teachers and students are not able to connect to networks for the purposes of learning and teaching. Therefore an enabler framework for this purpose becomes necessary. Those who connect to the Internet are not able to get precise and relevant content that meets their requirements and needs. This is due to poor internet connectivity, lack of semantics on content, inaccurate searches and information overload. This paper proposes a solution to some of the challenges by designing a conceptual ontology-based framework for mobile learning which could be used in rural secondary schools. The framework takes into account the following: a knowledge base, ontology, software agents, learning resources and learning/teaching content. Agents search for learning objects and extract knowledge according to learner and teacher/instructor profiles. The proposed framework would facilitate collaboration, sharing of ideas, instruction flow and access to learning and teaching content with accuracy, anytime from anywhere.

Keywords: learner profile, mobile learners, mobile learning, ontology, ontology based framework, teacher profile

JEL classification: L96, A21, M15

Introduction
Technology has been pivotal in the teaching and learning environments. In the 20th century radios and televisions were used to convey content to learners. Later came the Internet and computers to enhance learning. Today, there is a call for web based, blended and online learning, focussed on individualised content and collaboration. There is a shift from computers to mobile devices so that learning can be anytime from anywhere.

Mobile learning (M-learning) is defined as learning delivered or supported solely or mainly by handheld and mobile technologies such as personal digital assistants (PDAs), cell phones or wireless laptops (Attewell and Savill-Smith 2003). It entails online learning, virtual learning, distributed learning, networked and web-based learning with the following modalities: individualised self-paced M-learning online/offline and group – based M-learners synchronous/asynchronous (Rubens et al. 2011). Synchronous M-learning is timed and asynchronous is not timed.

Most rural secondary schools, if not all, require a physical face-to-face type of interaction in order to engage in the teaching and learning process in a formalised way. In rural Zimbabwe, most students travel long distances (+15km) to attend school. Usually classes start at 0800hrs and end at 1600hrs, Monday to Friday. Surprisingly, students are not allowed to use their cell phones during school hours. Schools do not harness the potential of these cell phones in the learning and teaching process so that interaction between teachers and students can be anytime from anywhere. Literature indicates that mobile phone ownership across the rural areas is skyrocketing. It is estimated that 68% of rural households own a cell phone (Gallup 2012) and this includes teachers and students.

Teachers and students rarely use cell phones in the teaching and learning processes. They normally use them for communication in social networks, Short Message Services (SMSs) and voice calls. Using the mobile phone, one has the potential of accessing the World Wide Web (WWW) to get learning materials and exchange content with each other. However, WWW has presented challenges in terms of poor internet connectivity, static and not well formed Hyper Text Mark-up Language (HTML) content, lack of semantics on content, inaccurate searches and information overload that has rocked the Internet infrastructure. Other learning technologies (e-learning systems) are not successful in the rural schools due to unavailability of suitable infrastructures. Ownership of cell phones was necessitated by the need for traditional communication; however no-one thought these cell phones could be used in the teaching and learning processes.

This paper aims to sensitise students and teachers to the potential that mobile phones possess in terms of accessing content, collaborating, exchanging ideas, engaging in homework and assignments in rural secondary schools. This is enhanced by the fact that most computing devices and technologies have become pervasive and ubiquitous (Chen et al. 2003). The envisaged solution is a design of an ontology-based framework to be used in the teaching and learning processes in a rural type school. The proposed framework would ease challenges (Gayeski 2002) such as poor internet connectivity, lack of semantics on content, limited bandwidth of wireless networks, limited resources available on mobile devices, technology costs, and reduce the information overload that compromises accuracy in information search processes. Physical interaction between teachers and students would be minimal, including the reduction of lassitude distances travelled by students.
Mobile phones in education

A mobile phone, also known as a cellular phone or cell phone, is a handheld device capable of sending and receiving messages and calls while moving around a wide geographical space (Hackemer and Peterson 2005). It connects to a cellular network provided by a mobile phone operator with access to public telephone networks. In addition to telephony, smart mobile phones offer other services such as text messaging, email, Internet access, short-range wireless communications, business applications, gaming and photography. Mobile phones that offer these services have more computing capabilities than do older models. Students and teachers in the rural areas are moving with technology as most of them have managed to buy smartphones with greater computing power than the previous ones. Most of the functions and capabilities of these phones have not been exploited due to the kind of set up that exists in rural secondary schools. Teachers and students predominantly use smart phones for social networking, SMSs and voice calls and rarely think about their potential in learning and teaching processes.

In other countries, especially South Africa, the use of mobile communication devices has gone beyond the traditional role of communication. It has been envisaged that these cell phones are capable of supporting teaching and learning processes, a notion that we are now taking to rural secondary schools. Mobile phones have evolved and brought a new paradigm known as M-learning (Hackemer and Peterson 2005). Browsing with cell phones is one convenient way for students and teachers to get online material and exchange educational material. Most mobile phones have browsing applications such as Opera Mini, Internet Explorer, Mozilla Fire Fox, Opera and Google Chrome incorporated in their software. It is envisaged that students and teachers can use browsers to check e-mails, read materials and engage in lessons from anywhere at any time. Mobile phones have downloading features which can be used by students and teachers to download various kinds of materials. Teachers can download videos and present them to students through a TV set available in the classrooms (Kafyulilo 2012).

The rapid growth of access to mobile phones around the world and in Africa in particular has the potential (Brown and Green 2001) to improve teaching, learning and institutional efficiencies to enable transformation of national education systems. Mobile learning applications can facilitate access to learning content conveniently and hence facilitate interaction stakeholders. The development of an ontology framework comes in as a new strategy for education that has implications in the way students and teachers interact. The ontology-based framework proposed in this paper consists of an ontology component driven by learner and teacher profiles for contextualising learning content, learning resources and content services and search agents which would extract the service or content or resource and present these according to user requirements, needs and preferences (Ghaleb et al. 2006). The architectural components are: student, teacher, learner profile, teacher profile, learning resources, learning content, content services, intelligent agents, ontology layer, World Wide Web layer and the knowledge base.

Ontology

Ontology is defined as a formal explicit description of concepts in a particular or specific domain with their properties and equivalence relations (Noy and McGuinness, n.d.). These concepts have properties and relations which constitute classes. Properties are features and attributes of concepts in a particular domain and these are also called slots or roles. An ontology and its individual instances of classes are referred to as the knowledge base. An ontology can also be defined as the semantic model representing knowledge about a particular domain in learning. There are different types of ontologies (Ngwenya and Chilumani 2013). These include static knowledge ontology which captures static knowledge about a domain. This category identifies four types of ontologies, namely Domain Ontologies designed to represent knowledge relevant to a specific domain type, Generic Ontologies which are applied to a variety of domain types, Representational Ontologies which formulate representation entities but do not define what is represented, and Metadata Ontologies that provide a vocabulary for describing the content of online information. The second category of ontologies is that which provides reasoning about the domain knowledge, thus being problem-solving knowledge. It includes Task Ontologies that provide terms specific to a particular task and Method Ontologies that provide terms specific to particular problem solving situations.

In our proposed framework, an ontology is used to add semantics to content, enable better learner modelling, efficient context acquisition and management and reusable customised learning content, learning resources and content services. Semantics is defined in the ontology as making computing devices understand information they are handling in a particular domain or subject area. Resource Description Frameworks (RDFs) are building blocks of ontologies and the Semantic Web (SW). Thus, an RDF is a framework for writing connections, allowing humans and computing devices to understand statements, process data and come up with answers to their questions (Daly 2009) and present content according to user needs, requirements and preferences. On the other hand, the building blocks of RDFs are subjects and objects whose connection is through the predicate (Davies et al. 2003, Fernandez et al. 2011). Subjects and objects are variables while a predicate is a property that describes a variable or it is a connection between variables. The subject and the object are connected by connector or predicate or property or verb. A standard Ontology Web Language (OWL) for describing the ontology is proposed because an OWL offers a set of primitives, mostly derived from description logic (Vanimba, Yasadha, Venkatech and Sowjanya 2013). Ontologies are an important part in mobile learning as they are used to represent terms, their relations and properties so that the content becomes explicit to the user.

Ontologisation

Ontologisation is the process of defining ontology classes, arranging them in taxonomy and establishing their relationships. The proposed framework is based on Class Concept from which classes such as Resource, TeachingContent, ContentServices, ConceptRole and
LeanerProfile are established. Figure 1 shows the graphical representation of the classes which are interpreted as sets and individuals.

The relationships are pointing at the descriptions of taxonomic structures of an ontology:

- hasResource points to resources that are intended for use by the students and teachers.
- hasTeachingContent points to the content in the Resource that the students would use for knowledge acquisition.
- hasContentServices points to the services provided by the content so that students engage and work with content, learn from content and create content in mobile devices.
- hasRole points to the role played by the content in knowledge development and acquisition. The concepts and content services in turn support students in their learning processes where the needs, requirements and preferences are of paramount importance.

It is important to note that the above is just a partial ontologisation for the purposes of grasping the concepts in the learning and teaching arrangement and is bound to be scalable.

Methodology for the development of the framework

Several research works indicate that there is no fixed single methodology or process for ontology development. The methodology depends mainly on the ontology purpose and its application (Noy and McGuinness, n.d.). The only two steps that are fundamental to ontology building process are ontologisation and operationalisation. Ontologisation is the step for designing the conceptual ontology and operationalisation is a step for coding the conceptual ontology. In this case, the ontology based framework is designed following a creative design methodology that involves a combination of literature surveys for eliciting the design requirements and conceptual designs for modelling the proposed ontology based framework.

The creative design methodology is a formal methodology for finding practical solutions to problems immediate to the end users (Lytras et al. 2003). It is solution-based or solution-focused. It has found its way and been successfully used in the area of Artificial Intelligence (AI). The methodology enables innovation that has user-centred models for application development to meet end-user needs. The main technique used is value proposition and contextual design with the purpose of contextualising and appreciating user needs. The methodology is structured in a manner in which the user insights are placed between the problem and solution. Thus the innovation occurs within the limits of the appreciated user’s contextual setting ie learners and teachers in rural secondary schools. The outcome of this methodology is an integrated approach that focuses on collecting user insights on mobile learning in secondary schools from literature surveys and interviews, translating them into an ontology-based framework for teaching and learning.

The proposed framework offers ontology descriptions in terms of the relationships between resources. There is also an addition of semantics so that content becomes reusable and flexible, turning the whole infrastructure into a Semantic Web (SW). Agents extract and interlink relevant content and gather analytics from the same content. This would be regarded as a unique setup in rural schools. The uniqueness is portrayed by the fact that there is a shift from information processing to knowledge processing. The SW makes provision for mobile device-understandable and interpretable content, intelligent agents to handle content, explicit declaration of knowledge for access, integration and extraction and the support of automation and reuse across applications and domains, allowing structured description of content.

Conceptual framework

The proposed framework was designed following the SCORM (Sharable, Content, Object, Reference, and Model) e-learning standards proposed by Protus as shown in Figure 2. SCORM defines and delivers interoperable specifications for exchanging and sequencing learning objects, standardising learning and teaching methodologies.

The framework consists of a knowledge base with terms, their relations and attributes. The next levels are ontology and software agents representing data and

![Diagram](image-url)
An ontology-based framework for mobile learning in rural secondary schools

The other layer is composed of learning resources which can be in the form of texts, videos, software or any materials that teachers or learners use to acquire knowledge, learning/teaching content as pieces of information delivered to students for knowledge acquisition, and content services which enable mobile users to engage with content, work with content, learn from content and create content on mobile devices. In this way, learners and teachers can access content, collaborate, exchange ideas and work on assignments according to user profiles i.e. learner and teacher profiles. This is facilitated by software agents that reason on the framework to extract objects for users.

How the framework works
The teacher and the student interact in the following way, using what is termed Student-Teacher Interaction Algorithm (S-TIA). The algorithm allows teachers and students to work in cooperation to achieve their goals in teaching and learning, in which the student is placed at the centre stage. On the side of the teacher profile, students are given assignments, instructions or some initiation of collaboration. In the case of assignments, students work on them and send back the answers. Thus the developed framework assists students in doing assignments or solving problems. The domain ontology in the framework expresses knowledge and concepts relevant to assignments and problems presented to students. Solutions to problems or assignments presented to students are defined in the ontology-OWL files and depending on the learner profile, students are able to semantically search for learner content, learner services and learner resources using software agents. These are then presented to him/her in a precise and relevant manner in accordance with his/her user needs, requirements and preferences. In this way, students give solutions to assignments or problems and results are sent to the teacher profile for assessment and evaluation and in turn feedback is given to the students. The framework gives the opportunity for learners and teachers to improve the teaching and learning process resulting in improvement in performance. It also gives time for analysis of the solutions given and then provide advice on improvement, i.e. provide learning suggestions based on solutions, course material, domain content and methods used.

In this scenario the student or teacher initialises the session from the mobile phone by presenting a problem/assignment. The role of the student is to solve the problems/assignments. The solution is then sent to the teacher for assessment and evaluation and the feedback is then sent to the student. This scenario is facilitated and handled by an ontology-based framework which presents knowledge and concepts/terms relevant to the problems and assignments attended to by the student.

Discussion and Conclusion
The ontology-based framework presents a unique scenario in which rural secondary schools benefit by using their mobile phones and the already existing infrastructure in a rural setting. Ontologies allow the presentation of knowledge in the form of a conceptualisation (Ghaleb et al. 2006) so that information is automatically and semantically processed to allow improvement in the teaching and

![Figure 2: Proposed ontology-based framework](image-url)
learning processes. Students and teachers are able to work from anywhere and at any time using their mobile phones, minimising the physical face to face scenario which wastes a lot of time and other resources. Students and teachers are able to access learning resources, learning content and content services in a precise and relevant manner using intelligent agents deployed in the ontology framework.

The developed framework is in line with e-learning requirements/standards, proposed by Druker (2000), to deliver individualised, comprehensive, dynamic content in real time aiding the development of communities of knowledge with links to students and teachers. The dimensions coupled in the development or design of the framework entail: delivery, responsiveness, access, symmetry, modality, authority, personalisation and adaptivity. On delivery, students determine the agenda in learning, while responsiveness allows students to respond to problems at hand or with the environment. Most importantly is access, where students have access to content resources and knowledge, which is something rural schools are not able to find. Symmetry would call for an integrated activity among teachers and students and that modality refers to the fact that learning is a continuous process. Students and teachers must both have authority over the content they are using for knowledge acquisition.

The content itself must meet user needs, requirements and preferences, thus be personalised content. Adaptivity requires that content be dynamic, thus it should change as needs and requirements change.

In this paper, it has been envisaged that ontologies can improve knowledge presentation and contribute to the teaching and learning processes in rural secondary schools and that they have a potential in the application domain of information processing and retrieval. With increased development and availability of ontology tools, researchers will take up the challenge of developing ontologies in the area of mobile learning. This could make a difference to subsequent generations to adopt and adapt these ontologies to match needs, requirements and preferences of teachers and students. The number of documents that are machine readable would definitely increase, making a big step towards the SW and ontology utilisation and their application.

In the novel development of the framework, it is important to highlight the fact that more work has to be done in the development of domain ontologies so that they are incorporated into the implementation of the framework. The proposed framework would capture and incorporate learning content, instructions, learner related and metadata aspects so as to support learning technology systems. The framework would also help in structuring and exploring different applications of ontology technologies especially in the area of content development. However, the given approach does not impact directly on the quality of content and pedagogical requirements of teaching and learning processes, though the benefits are noted in extended availability and access to semantically and ontologically developed mobile learning systems with lower educational costs. Through the framework, information would be expressed in a precise, machine interpretable form for agents to process, share, understand and reuse terms describing data, making applications interoperate at syntactic and semantic levels.

Emerging from the discussion is the fact that the relationship between knowledge and content becomes explicit when using the SW and ontology technology in searching, writing, and gathering, organising and developing content. This would enable teachers and students to access content, collaborate, exchange ideas, do homework and assignments in rural secondary schools. These technologies come with sharing and reuse of learning resources in different contexts and environments. Currently, there is not much that has been done in the area of domain ontology development for mobile learning in specific subjects or courses. However, the SW and ontology technology have been exploited successfully to
some extent, though some promises by these technologies remain unaccomplished in other areas.

Recommendations are that content developers use available SW and ontology technologies for teaching and learning to improve teaching/learning and research. This would cultivate and bring about an appreciation of the SW for mobile learning systems. The other important future development would be to migrate mobile learning sites to semantically configured systems to facilitate teaching and content development processes. It is also important to note that this paper did not discuss the geometrical and software requirements for mobile phones, a situation that would require further research in the implementation of mobile learning systems.

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