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OntoCog: A Knowledge Based Approach for Preschool Cognitive Skills Learning Application

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Abstract

In present work, the theoretical and development details of a child-friendly mobile application to enhance cognitive skills of preschool students are presented. Cognitive skills are a vital part of the curriculum at all level of education especially preschool learning. Currently considerable numbers of mobile applications are available for child learning that claim educational goals but they only dispense information without considering pedagogical theories and models. In contrast those applications that were primarily developed to achieve educational goals are only available to a selected audience mainly researchers. Also the nature of existing mobile application is static content delivery in which previously created contents are stored for repetitive use. This static nature jeopardized individualized and cognitive skills learning. The objectives of the present work is to overcome this static nature of content delivery by proposing a knowledge model named OntoCog with mobile application for dynamic content creation that follows constructive pedagogical theories. A mobile application named Cognitive Skills (CogSkills) is developed to evaluate proposed model. As a result the dynamic nature of the CogSkills provides a clear advantage over existing static nature mobile applications.

Keywords: Intelligent Tutoring System; Semantic Web; Cognitive Skills; Preschool; Mobile Application;

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1. Introduction

The role of technological gadgets in young children's learning is highly noticeable in today lifestyle because three to five years old children spend their time at home and their parents control their activities and provide required resources. These technological resources are mainly television, games consoles, mobile applications and web contents (Lydia Plowman, et al., 2012). Today's technological culture is reshaping the children's learning by introducing more interaction of children with technological resources mainly for entertainment and learning. Similarly researchers are elaborating and identifying the potential power of this technological culture (Facer, et al., 2004).

Previous technologies such as television do not provide physical interaction (such as motor activities) but recent touch-screen mobile environment provides both physical and digital interaction. Perry and Dockett (Perry, & Dockett, 2002) reported that much of the learning is accomplished only by children's own interest and excitement during learning, without the use of formal contents. Interaction with mobile applications provides interest and excitement to the children and it is very much clear that learning gain is high with the use of technological resources (Subarna & Wan Fatimah, 2010; Wan Fatimah, Ainol Rahmah, & Shafitra, 2012).

Existing mobile applications possess several shortcomings which we will address and overcome with our proposal. Currently considerable numbers of mobile applications are available that claims educational goals but they either only dispense information (previously stored contents for delivery) or target a single objective (motor activity, memory building, sounds and words pronunciation etc.) with limited contents (Wan Fatimah, Ainol Rahmah, & Shafitra, 2012; Aruhat Technologies, 2012a; Aruhat Technologies, 2012b). In contrast those applications that were primarily developed to achieve educational goals are only available to a selected audience mainly researchers (Abbas, Ahmad, & Kalid, 2012; Ghee & Chai Quek, 2007;Ghee, Chai Quek, & Maskell, 2010; Carbonell., 1970; Clancey, 1982; Sleeman., 1987). Available applications for kids are mainly coloring games, vocabulary games, and memory building games (Aruhat Technologies, 2012a; Aruhat Technologies, 2012b; City Games, 2012). Memory is one of the cognitive skills but the current applications memorize objects in isolation that prevent attainment of the knowledge associated with that object being memorized. Similarly other cognitive skills found in preschool curriculum are not available in current mobile applications (details of other cognitive skills are provided here in present work). Contents used in current mobile applications are static in nature that does not change based on user understanding and their expertise level. The primary reason for the static contents in existing application is because they use content based approach rather than any model approach. Previously created contents are stored within application for delivery. This work proposes dynamic creation of contents by establishing a knowledge model with the application code.

In present work, the theoretical and development details of a child-friendly mobile application to enhance cognitive skills of preschool students are presented. The proposed work is based on solid educational goal that is cognitive skills tutoring of preschool children. To achieve this goal we follow the recommendations provided by educationist and curriculum developers through the use of provided motor and physiological activities. The present work accompanies different cognitive skills such as classification and relatedness in addition with memory skills. Last but not least the static nature of existing applications is enhanced to dynamic content creation through the use of a knowledge model named OntoCog that is based on Ontology.

Ontology, an essential component of semantic web technologies provides a common and formally defined vocabulary of concepts of a domain, along with the meaning of each concept, its properties and the relationships among them. During the last decade, areas such as knowledge management, intelligent information systems and education received high attention on ontologies and their use in applications (Vladan Devedzic, 2006).

The rest of the paper is organized as follows. In the Section 2 provide analysis and discussion of related work. The details of proposed knowledge management technique and technologies are presented in Sections 3. Section 4 describes the implementation details and evaluation results of the proposed mobile application based on proposed knowledge model. Conclusion of the work is provided in Section 5 with directions of our future research.

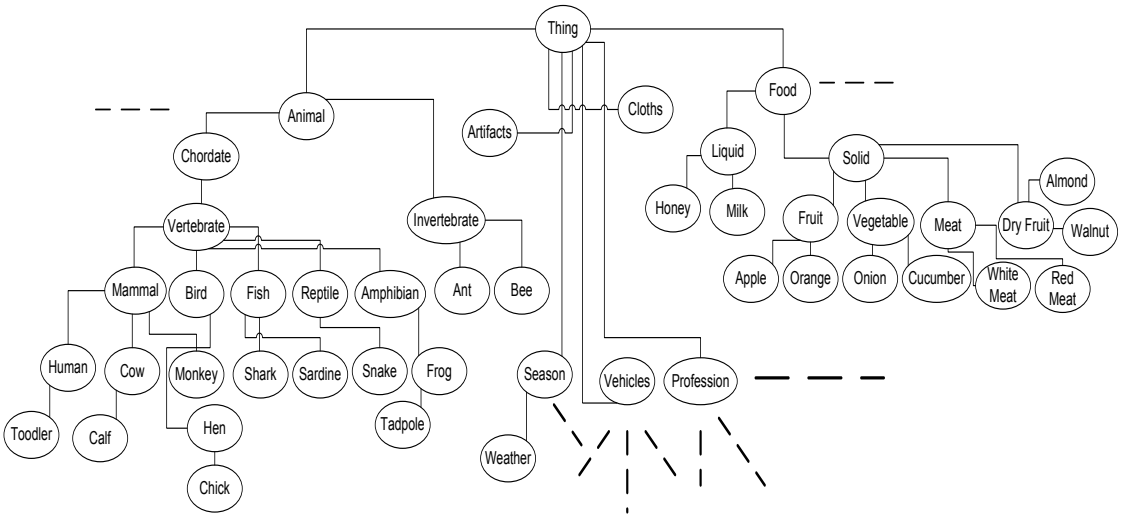

Fig. 1. OntoCog Ontology Snapshot

2. "Related Work"

This section provides a review and analysis of existing work related to the present work. Review and analysis is comprised of intelligent tutoring systems, cognitive skills, pedagogical models and mobile learning applications.

Analyzing existing work reveals that the primary need to overcome shortcoming identified in previous sections is the domain models, that is, domain knowledge represented in a way that allows the system to generate dynamic contents and support pedagogical theories. A similar work with the present work was done by Abbas et.al.(Abbas, Ahmad, & Kalid, 2012). An application named Self Learner Tutor (SLT) was proposed for preschool children. SLT is based on Resource Description Framework (RDF) a component of semantic web technologies. Present work uses Ontology that is a component of semantic web but it is at a higher level in semantic web layered architecture than RDF. Ontology support complex and dense knowledge modeling as compared to RDF model. Similarly SLT designed for PC workstations while present work addresses mobile applications.

A software application named Epilist was proposed by Ghee & Chai Quek, 2007; Ghee, Chai Quek, & Douglas, 2010). Sets are used by Epilist to model the domain knowledge. Related objects are grouped together based on their related property into one set called semantic network. A semantic network is applicable only if it is complete and unique i.e. a set with containing all items are classified correctly is called complete. For example grouping items in male and female is a complete semantic network. Similarly a profession set is not unique because several items can hold different professions at a same time. In a sematic network different properties are used to make such classification complete and unique. Epilist is a list-making game. We have achieved conceptualization of complete and consistent reality of

the domain by using the advanced technology named Ontology. Ontologies natively provide a way to model complex domain knowledge completely and consistently.

A survey was conducted to investigate Malaysian preschool curriculum for modeling it to a mobile application (Abbas, Ahmad & Kalid, 2012). Preschool curriculum in general is concept understanding (MOEM. 2001). Students at age of 3 to 5 years are primarily taught about concepts of the real world around them. These concepts range from color recognition to science processes. At the initial level children are introduced to objects followed by their properties and later classification of objects for example animals and birds, fruits and vegetables etc. Classification is one of the cognitive skills found in preschool curriculum. Relatedness is another cognitive skills found in preschool curriculum that is knowledge about things that are related through some property or relationship for example Fireman with Fire, Bee with honey, Frog with insects etc. Classification and relatedness both make reasoning skills that is child can reason about implicit things such as match box and danger, deep water and drowning etc.

The practices used to teach cognitive skills in current school environment are through the use of textbooks and worksheets. The hardcopy learning materials mainly follow match the column, circle an object and mark a tick or cross for conducting classification and relatedness cognitive skills exercises. We follow the same in our proposed application.

The game like mobile application named SPELL IT! was designed for children to build English vocabulary (Wan Fatimah, Ainol Rahmah, & Shafitra, 2012). The application follows the traditional content delivery model i.e. limited number of words and there English translation was stored for practice and exercise. A multiplayer mobile game was presented by Palazzi & Maggiorini (2011). The game players were connected through wireless connectivity. This game (Palazzi & Maggiorini, 2011) is a color recognition game. Botzer & Yerushalmy (2007) highlighted the learning experiences of children through mobile learning. Two mathematics applications mainly for 2-d graph creation are used for evaluation. Results of this work identified the potential and benefits of mobile learning.

Some problems related to the interface designing of software for kids were identified by Karuovic & Radosav (Botzer & Yerushalmy, 2007). These problems are limited usage of electronic devices and difficulties while interviewing the end users about their demand. Interface designer must design the interface to clearly show the child's work tasks which he/she has to perform. Software designer must also understand the mental system of the child (children psychology) while performing some tasks and tools required to accomplish underlying activities. In our proposed work we followed the same interfaces found in hardcopy learning materials because children as users are very much familiar with those interfaces. Tools provided to accomplish an activity are tapping the screen and drawing a line with the finger between two objects.

3. "OntoCog Model"

Existing mobile applications are mainly designed for content delivery where previously created contents are stored for user to use. This static content delivery model lacks individualized learning and subsequently does not support constructive pedagogical model. For example application like (Aruhat Technologies, 2012a; Aruhat Technologies, 2012b) provide photos of an animal as slideshow and click option to hear their sounds. These applications just dispense information that makes them unable to support the complete knowledge construction of a child.

Next generation e-learning or m-learning (mobile-learning) is moving toward semantic web technologies as their technological foundation (Vladan Devedzic, 2006). Ontologies an essential part of semantic web technologies is a knowledge representation or modeling approach. Generally, ontologies are defined as representation of shared conceptualization of a particular domain. In our case here the domain is preschool cognitive skills. The primary reason for using ontologies for the present work is because

ontologies by definition provides a way to formally specify the vocabulary of terms and their semantics. The same methodology is used for teaching cognitive skills i.e. a concept and its associated semantics formally specified in an Ontology are taught through using some representations of objects or text.

More specifically, ontologies provide a way to represent formally and explicitly concepts of a domain, their associated properties and relationships (Gascueña, Fernández-Caballero & González, 2006). Cognitive skills of classification and relatedness are highly dependent on properties and relationship of things. Ontologies along with rule-based systems are also opening new horizons in artificial intelligence domain. Since our proposal is an initial work in this domain that can be achieved with ontologies self-resources without using any rule-based system. The present work can easily be extended to higher details with any rule-based system but it is not appropriate for the scope of this paper.

Ontologies natively provides solution to all requirements for modeling of our domain i.e. conceptualization, classification and relatedness. Concepts are represented by classes in ontologies (Antoniou, 2004). For example, a class of Mammals represents all mammals. More specifically animals that are mammals become instances of this class. A class can have subclasses that represent concepts that are more specific than the superclass. For example, we can divide Animal concept into Vertebrate and Invertebrate. Properties of classes and their instances are called slots. For example Cow is an Animal and it produces Milk. In this example there are two slots: the slot isA with the value Anmial and the slot Produce with value Milk. In this case, all the instances of Cow have slots isA and Produce.

All concepts are formally defined as classes in ontologies. Similarly the hierarchical structure (superclass-subclass) provides single as well as multiple classifications of concepts. Concepts/classes in ontologies are connected to each other with properties that provide relatedness among concepts. In ontologies, concepts or classes at top level hierarchy are more generalized than the lower ones such as Animal. These generalized concepts are split into more specialized concepts at lower levels in hierarchy such as Vertebrates and Invertebrates.

An ontology specifically for preschool cognitive skills modeling is populated from WordNet 3.0 (Miller, et al., 2012) using WordNet provided nonus, verbs, adverbs and adjectives. Populated ontology at its abstract is shown in Figure 1. Concepts in WordNet are grouped in semantically related synonyms called synsets. Synsets provide interlinked information among concepts that creates a semantic-network. A survey was conducted to investigate the knowledge found in Malaysian preschool curriculum (Abbas, Ahmad & Kalid, 2012). Textbooks and teaching practices followed in different selected schools mainly operating in branches were analyzed and all concepts found in that teaching material were enlisted. These enlisted concepts are then represented in ontological representation with the help of semantic knowledge found in WordNet about these said concepts.

4. "Implementation & Results"

An application named Cognitive Skills (CogSkills) has been developed to validate our proposal. CogSkills is developed for Android platform using Androjena version 0.5 (Androjena., 2012). Some screenshots of CogSkills are shown in Figure 2. Ontology is ported on mobile in the form of an extensible markup language (XML) file. Every concept of ontology is associated with a pictorial representation. The working area of the application is designed same as hardcopy learning material such as worksheets and textbooks.

CogSkills utilizes the structural and semantic knowledge represented in the Ontology for content generation. Ontology represents concepts in hierarchal order where super-concept is more generalized and sub-concept is more specific. The properties defined within ontologies provide relationship among concepts. Concept hierarchy works for the classification cognitive skills contents and property

relationships supports relatedness skills contents. Screenshots shown in Figure 2 depicts two properties Eats and Produce between Animal and Food concepts.

The cognitive skill of classification is efficiently addressed by CogSkills. At the start screen user can select their choice of objects to practice classification skills. As an example in Figure 2 user has selected Animals as his/her preferred object. A random objects option can be selected to assign the decision of objects selection to the application.

As shown in Figure 2, pictorial representation along with textual label is shown to provide clear understanding to the children. Screenshots depict relatedness cognitive skills exercises of same objects in different ways. A child can either flip cards by tapping the mobile screen or match related card in match the column fashion. The motor activity of drawing a line can be practiced in match the column exercises. Same exercises can be visualized in different formats as per user selection. Multi-associative nature of domain model supports the enhanced cognitive skills learning in CogSkills. That is, one object can be matched with one another or may be with more than one. For example in exercise 'what animal produce?' goat and cow can be matched to both milk and meat as they are the sources of both of these foods.

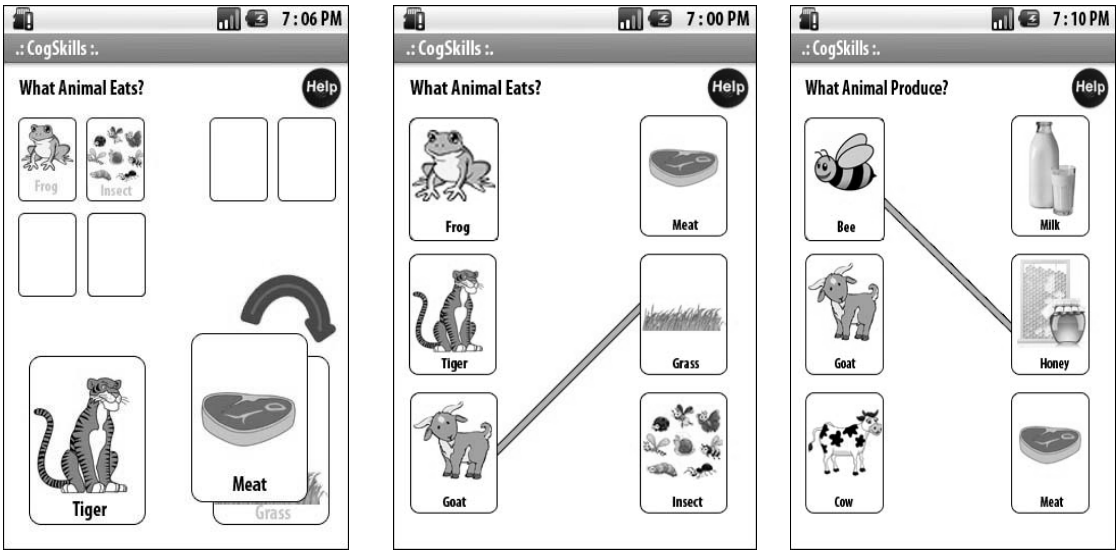

Fig. 2. CogSkills Screenshots

CogSkills follows both instructional and constructive pedagogical models. Any content can be stored (instructional model) for later use and also contents can be generated dynamically (constructive) on the fly. An experimental study was performed for evaluation of CogSkills. CogSkills was run and tested several times. Dynamically created contents for relatedness cognitive skills learning were generated through either direct or indirect relationship present between concepts of the ontology. Since emphasis of our proposal is more toward technical details of knowledge based mobile application rather than socio-impact of mobile learning, CogSkills is tested technically without involving real users. Manual evaluation of dynamic contents generated from CogSkills was done. CogSkills generate a new content based on the user profile. A user profile has been created and CogSkills was experimented for content generation. Every new content generated was evaluated by us for accuracy and acceptability. Table 1 shows evaluation results of dynamically created contents. These results show the accuracy and acceptability of CogSkills and applicability of Ontological model within a mobile application.

The dynamic contents generated from CogSkills are separated in four categories shown in Table 1. A small portion of dynamic contents are generated repeatedly (18.51%) because CogSkills also involve previously stored or authored contents for generation of the new contents. Similarly very few contents (7.40%) have erroneous objects e.g. in one content a Jug and a Table are shown under relatedness skill. Some contents generated are marked as high difficulty contents (7.40%) for children between 4 and 6 years age. The remaining correct (66.66%) contents are distributed among students to solve.

The diagnosis for cause of erroneous contents is the inconsistency present in Ontology. Similarly the high difficult contents were produced because Ontology contains some very complex properties and relationships among concepts that are out of the scope of child ability.

Table 1. Evaluation Results

Dynamically created contents (n=27)			
Correct	Erroneous	Repetitive	Difficulty Too High
18 (66.66 %)	2 (7.40%)	5 (18.51 %)	2 (7.40 %)

5. Conclusion

In this paper, use of Sematic Web technologies and in particular ontologies for development of mobile application for preschool cognitive skills learning is presented. Details of knowledge modeling of preschool cognitive skills have been provided. This ontology based approach provides ease to both knowledge modeling and software development activities. The existing instructional or content delivery mobile applications can be replaced with constructive or dynamic applications with the use of proposed knowledge model. The cognitive skills of classification, relatedness and memory are implemented and demonstrated in a mobile application named Cognitive Skills (CogSkills). The dynamic content generation ability of the CogSkills is a clear advantage over existing static content mobile applications.

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