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A SEMANTIC WEB BASED FRAMEWORK FOR PRESCHOOL COGNITIVE SKILLS TUTORING SYSTEM

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ABSTRACT
Intelligent tutoring system (ITS) is a contribution of the artificial intelligence domain, which supports the pedagogical activities. The development of a constructive intelligent tutoring system following psychology, intelligence, interactivity, creativity and personalization for any real domain is highly complex. To address this complexity, a semantic web based framework, called MySekolah was presented in this paper. The proposed framework comprise of integrated set of models using ontologies i.e. domain model, student model, assessment and expert models. The goal of the proposed framework is to provide an overall structure for the construction of an intelligent tutoring system. More specifically, to model the domain knowledge and generate learning contents through the use of expert based reasoning technique. As a sample, modeling of the preschool cognitive skills is demonstrated. A prototype application is developed to validate the framework. Finally, evaluation shows the correctness of the cognitive skills learning content generated from the modeled ontology.

Keywords: semantic web, ontology, intelligent tutoring system, framework.

INTRODUCTION
The value of creativity in early childhood education (3 to 6 years age) is well understood by educators and they are recommending it as a major component of the preschool curriculum. This required creativity in individuals can be achieved by cognitive, environmental and motivational variables [1]. The scope of the present work is limited to cognitive factors only. Cognitive skills domain at its abstract is intellectual performance and more specifically are mainly classification, relatedness, spatial, science, mathematics and reasoning and problem solving skills [2], [3]. Cognitive skills are a vast domain encompasses of several dimensions in executive and general abilities. Generally it reflects the abilities to build IQ, construction of general knowledge through vocabulary or objects representations or enhancing intellectual performance. Executively cognitive skills are perception, memory, comprehension, decision making, problem solving, and reasoning, and functioning that may occur at the individual or the group level. Cognitive skills are an essential part of preschool curriculum. Moreover, preschool cognitive skills are all about knowing the real world. In this regard, the cognitive skills tutoring through a tutoring system require the modeling of the real world in a computer understandable representation. This leads the present work to a proposal using Semantic Web Technologies namely Ontologies. Ontologies by definition [4] are the structural frameworks for organizing information as a form of knowledge representation about the world or some part of it.

The learning contents used for teaching cognitive skills at preschool level are of the type generic knowledge. Generic knowledge is said to be the knowledge about kinds of things [5]. More specifically, generic knowledge in artificial intelligence (AI) and Semantic Web domain of research is about understanding the basic facts of everyday life e.g. Sugar is Sweet, Mammals produce Milk etc. These facts of everyday life which Semantic Web is trying to model through Ontologies are same for the preschool cognitive skills learning contents. From this, a relationship appears between preschool cognitive skills learning contents and the Semantic Web technologies.

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. Despite the vast application of Semantic Technologies in different fields of the real world, the semantic aspect of Semantic Technologies has not been fully applied to intelligent tutoring systems, and particularly for developing and delivering reusable learning contents. The research into Semantic Technologies based intelligent tutoring systems (ITS) suffers from several limitations including high complexity of consistent and complete modeling of domain knowledge, student behavior, profile and interaction, pedagogical activities such as instructional or constructive. On the other side, the benefits reported from semantic technologies are that Ontology has not only been developed to provide a meaningful structure to syntactic information rather it can be used for modeling of the domain knowledge, student model, pedagogical model and reasoning to generate learning contents.

This work provides a conceptual framework for semantic web based tutoring system named MySekolah. Each model within the framework is identified by analyzing the literature, existing applications, curriculum and current practices followed in the schools and conducting an initial technical feasibility study. MySekolah is validated for the preschool cognitive skills tutoring but it can also adapt to other educational levels such as kindergarten, language learning and IQ improvement. The proposed framework provides a foundational ground for the development of semantic web applications in the real life scenarios especially in education.

The rest of the paper is organized as follows. Section 2 reviews the related work. Section 3 presents the details of the semantic web based tutoring system framework. Section 4 demonstrates modelling of the preschool cognitive skills through ontologies. In section 5 evaluation of proposed ITS is conducted and results are provided. Finally, Section 5 concludes the paper.

RELATED WORK

Use of Ontologies as a formalism to share knowledge and information among web systems and agents is becoming common in current research. A tutoring system named Protus [6] was proposed for learning java programming using semantic web formalism. Protus is a recommendation system that use learning styles of a learner and provide personalization. Their work use an ontology and semantic web rules (SWRL) for providing recommendation to the learning according to his learning style. Protus addresses most of the models of the overall semantic web based ITS framework. Similar to Protus, Sanchez *et al*. [7] provide feedback for open questions while conducting assessment tests. Feedbacks are generated through the use of ontologies and semantic annotations. Student's provided annotations and question's annotations are compared for sematic similarity to produce the appropriate feedback. Expert model is excluded in this work as only pre-defined feedbacks are provided to the user based on semantic similarity measure.

An approach using Web 2.0 for organizing and sharing learning contents authored by community of teachers and students was propped by Cabada *et al*. [8] The tutoring system was named EUDCA. EUDCA is an adaptive authoring system that brings learning contents to the user according to his learning style. Self-organizing maps (SOMs) are used for prediction of best learning style. With SOM (an expert model), EUDCA has eliminated the teacher from the learning environment. EUDCA was tested for collaborative and mobile learning scenarios.

World Wide Web (WWW) especially Semantic Web is a primary focus of the researchers for the eLearning solutions [9]. Mainly researchers have contributed to the domain, student and expert modeling of intelligent tutoring system but assessment is sparsely addressed. Castellanos *et al*. [10] proposed an assessment technique for open questions evaluation using Semantic Web Technologies. Similar to Protus [6], the assessment technique uses domain ontologies, annotations and semantic similarity. Natural language open ended questions are experimented as a case study for evaluation of the proposed assessment technique.

Student model holds the students profile that is required for navigation among different contents. Every interactions, mistakes and solutions done by student are stored in student model. Student model strongly relates with the assessment model to conceive student understands about any given concept or a learning content. Assessment model can be a statistical model or a heuristics based model to evaluate the student understanding or learning.

A fuzzy set approach was implemented to assess the learning process outcomes by Ma and Zhou [18]. Similarly the following fuzzy set approach for assessment was used by GDSS [17]. Authors have reported enhanced learning by this fuzzy set approach assessing and comparing control and experimental groups [18]. A prototype application named Cogito was developed by Olds *et al*. [19] to measure accurately and inexpensively the critical thinking ability of a student. Cogito uses pattern recognition between student data and traditional models of intellectual development using neural network technique. Weon and Kim [16] proposed an assessment system for achieved learning by a student in comparison to the traditional numerical values assessment. Authors have used fuzzy linguistics variables approach for evaluating elementary school students.

Next generation e-learning or m-learning (mobile-learning) is moving toward semantic web technologies as their technological foundation [4]. 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 provide a way to formally specify the vocabulary of terms and their semantics. This feature of the Ontologies is utilized for teaching the cognitive skills i.e. a concept and its associated semantics formally specified in Ontology are taught through using some representations of objects or text.

The literature related to intelligent tutoring system has not addressed the pedagogical issues as shown in Table-1. The present work put consideration over pedagogical issues along with technical details because ITS is a supporting aid to the current pedagogies. Hence, an ITS must include a solution for the implementation of pedagogies with in its proposal. Following can be viewed in the next section under proposed framework.

Table-1. Summary: components of the intelligent tutoring system framework.

Research work	Domain model	Student model	Expert (Person)	Expert model	Assessment model	Interface model
Latham, 2010, 2012 & 2014		X		X		X
Sánchez, 2012	X	X			X	
Vesin (Protus), 2012	X	X		X		X
Castellanos, 2011		X			X	
Caravantes, 2011	X	X				
Cabada, EDUCA, 2011	X		X			X
Clemente, 2011		X				
Epilist I & II, 2007 - 2010	X		X			X
Žitko *et al*. 2009	X					
Mitrovic, 2009	X					
Stankov TEx-Sys,2008	X					
Botzer, 2007						X
Dolog, 2007		X		X		
Hatzilygero & Prentzas, 2004		X			X	X
Nussbaum, 2001	X		X			X
Total	9	8	3	3	3	7

MYSEKOLAH FRAMEWORK

Table-1 presents the components of a general tutoring system framework. Exiting literature addressed individual components because each component is a separate research domain in its own. Nearly all of the cited research had proposed the domain modeling techniques. Reviewing the literature reveals a strong connection between assessment model and the student model. Assessment model depends on the student model as it can be seen in the columns third and sixth of the Table-1. The student profiling [11] (all activities and actions of a user) or the student model is considered to be a mandatory thing for assessment purpose. Several works had used expert's interventions for correction of the domain model during system usage. While several others have modeled the expert knowledge using ontologies. This modeled expert knowledge is used to compare with student actions for navigation purpose. In present work, the expert model creates the new contents from domain model for student to experience a learning concept from different perspectives. Expert model in existing works mainly represent expert knowledge explicitly using formal representations such as sets, semantic networks or ontologies. The present work in contrast, represent enhanced expert knowledge using semantic web rule language (SWRL) rules [12] and implicitly infers the new knowledge.

The proposed framework of the semantic web based tutoring systems is shown in Figure-1. All boxes in Figure-1 depict the components of the tutoring system framework. A brief overview of each block is presented here.

Domain model contains the domain knowledge that is modeled using some formalism i.e. Ontologies in the case of present work. Previous work has used sets and knowledge structures. Student model holds the students profile that is required for navigation among different contents. Every interactions, mistakes and solutions done by student are stored in student model. Student model strongly relates with the assessment model to conceive student understands about any given concept or a learning content. Assessment model can be a statistical model or a heuristics based model to evaluate the student understanding or learning.

Pedagogical model concerns about the pedagogical approach a tutoring system follows either instructional or constructive. The overall design of the system depend on pedagogical model as if instructional is followed then the tutoring system will take instructional material or contents as an input to conduct tutoring. On the other hand, the output will be a computer vision system, virtual reality, dynamic content generation (as the case of present work) or an expert system if constructional pedagogy is being selected. Curriculum sequencing or navigation is important part of pedagogical model in which difficulty level and prerequisites of the teaching material or learning contents are controlled and sequenced. Within pedagogical model, the present work mainly focus on cognitive skills tutoring. This block can be replaced with any other focused tutoring activities or research such as primary mathematics, higher education, language learning etc.

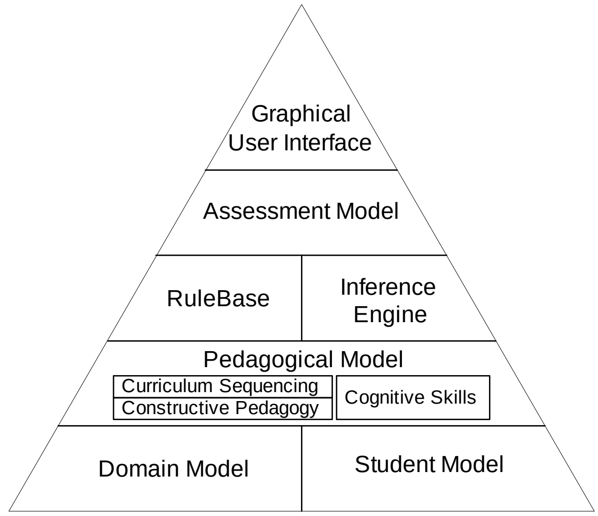

Figure-1. MySekolah framework.

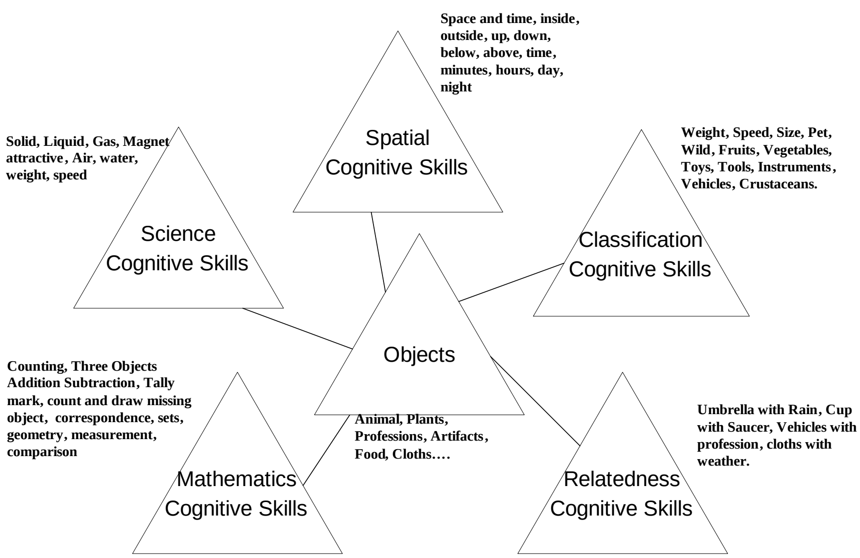

Figure-2. OntoCog ontology.

Content authoring rules generate the cognitive skills learning contents. Rules are represented using semantic web rule language (SWRL). Inference engine infers the logical consequences from the list of rules over modeled domain knowledge to conclude new relationships among concepts. With the proposal of rules and inference, the present work eliminates the domain expert (a person who manually receives actions of the user and create new links for further procedure) from the system as suggested by the previous work. The user interface module is responsible to display learning contents according to different cognitive skills representations defined by educationists. Interface module also handles the medium of representation such as online system, mobile, virtual reality or a desktop application.

ONTOLOGY BASED DOMAIN MODEL

The goal of the proposed work is to utilize the semantics of data i.e. modeled through the use of Ontologies to develop an intelligent (dynamic content creation) and interactive application for preschool cognitive skills tutoring. Researchers generally consider ontologies as the best way for modeling reality because of their semantic modeling ability. 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. 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 Animal 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. The domain and pedagogical models along with rules representation and designing of inference mechanism is the primary focus of this paper. In principal, the characteristics building of conceptual framework is based on unification of characteristics of the general tutoring systems and features of the semantic web technologies. The characteristics of the conceptual framework were realized by addressing the requirements specification which are: (1) constructivism realized by learning contents creation feature (2) reduction in time for creation of a learning content (3) learning contents generated are accurate and supports the preschool cognitive skills learning. A system architecture was designed to identify the source and sink of knowledge flow. Since individual model of the overall conceptual framework is itself a research domain, the present work has concentrated on ontological based domain modeling of the overall conceptual framework. The procedural details for designing the domain ontology (OntoCog) and its enrichment for associations, representation of rules and working of inference mechanism are discussed. The ontology (OntoCog) is populated in a systematic way from multiple knowledge sources i.e. WordNet, Dbpedia, Freebase and ConceptNet. The hierarchical structure of the OntoCog was constructed from WordNet synsets. Synset is a lexical organization of English words grouped into cognitive synonyms. The hypernym information from the WordNet is used for the class inheritance. Different senses of a word construct different classifications within OntoCog. OntoCog only models the concrete and abstract concepts of the preschool curriculum i.e. vehicles, animals, cloths, body parts, artifacts etc. Concrete concepts are the atomic concepts while abstract are some meaningful concepts. The concrete knowledge is modeled within OntoCog ontology using enrichment method whilst the abstract concepts are modeled by semantic web rule language (SWRL) rules.

The hierarchical structure of the OntoCog is constructed using hypernym and hyponym information from the WordNet. Each concept is represented in super or sub class hierarchy. Senses identify the type of the concept. During OntoCog construction, an extensive traversal was performed for extraction of any preschool concept from the knowledge sources while eliminating the inappropriate concepts. The OntoCog relationship enrichment is performed by extracting the relations among the modeled concepts from different knowledge source and enriching them with the meaningful associations. The enrichment starts with searching the relations available between two concepts. A simple search using the domain and range concepts is unanswered in most of the cases because a direct relation is not present between these concepts e.g. cow and the milk. ConceptNet provides a direct link between several concepts but the meaning of the provided link is unavailable. To resolve the meaning of the link, a search with domain and range concepts along with their concept type is performed. This type based search has broaden the search scope that is mostly answered by Cyc and Freebase knowledge sources. Every new knowledge extracted from the available knowledge sources is then translated into meaningful relation and modeled in the OntoCog. The OntoCog ontology is verified for inconsistencies after adding a new concept or relationship to the ontology. This verification is done through the use of reasoner like Fact++ or Hermit. In present work, the Fact++ reasoner was used for the verification of any inconsistencies in the ontology. Later disjoint, inverse and transitive relationships are inserted into OntoCog ontology using the same procedure. The inserted disjoint knowledge has eliminated several wrongly inferred relations among the concepts.

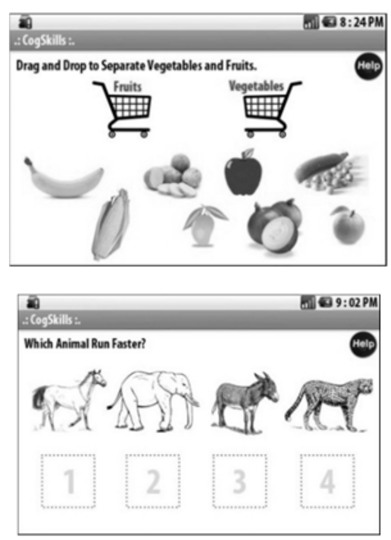

Figure-3. CogSkills screenshots.

EVALUATION AND RESULTS

An application named Cognitive Skills (CogSkills) has been developed to validate the proposed framework. CogSkills is developed for Android platform using Androjena version 0.5 [13]. Some screenshots of

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CogSkills are shown in Figure-3. 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. 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-3 user has selected Plants and 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-3, 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. As discussed in Section 1, presenting a same concept from different perspective gives better understanding. Figure-3 shows an example of brining same concepts under different characteristics (animal running speed, animal weight carrying capacity, animal size, etc). Answering correctly to all these exercises shows clear understanding by students. Learning contents shown in Figure-3 follows the ordering cognitive skill under mathematics. From usability aspect, user uses the drag and drop methods to fulfill this exercise. Showing a video related to speed and weight carrying capacity of animals etc before conducting the learning contents gives a very effective learning for the children. This proposal is a future work for our application and it can be easily accommodated by annotating the domain model concepts with video streams.

The evaluation of the proposed application is focused on evaluating the learning contents generated by the CogSkills for cognitive skills tutoring. Learning contents are evaluated based on Wechsler Preschool and Primary Scale of Intelligence (WPPSI) [14] and Wechsler Individual Achievement Test (WIAT-II) [15] intelligence tests by a senior educationist assisting the experiment. Subsets of the WPPSI (current version WPPSI-III) mainly related to performance cognitive domains were incorporated in the evaluation. Mainly all subsets that are associated with pictorial representation are used such as Information (child choose a picture from a group of four provided pictures based on queried cognitive skill), Picture Concept (child group pictures based on a common characteristics - classification or relatedness) and Picture Completion (child identify the missing picture or part of the picture - disambiguation). Mathematics concepts such as Numerical Operations (counting, adding and subtracting) and Math Reasoning (e.g. measurement, comparison, correspondence, geometry, sets etc) are included from WIAT-II.

Table-2. Learning contents generated by CogSkills during experiment.

WPSII, WIAT-II category	Cognitive skill content type	Total number of contents
Information (IN)	Classification	753 (12.92%)
	Relatedness	639 (10.96%)
Picture Concept (PCn)	Classification	794 (13.62%)
	Relatedness	647 (11.10%)
Picture Completion (PCm)	Disambiguation	540 (9.27%)
	Sets	139 (2.39%)
	Colors. Color Patterns	500 (8.57%)
	Shapes, Shapes Patterns	156 (2.67%)
Number Operations (NO)	Counting	467 (8.01%)
	Three Objects	139 (2.39%)
	Tally Mark	115 (1.97%)
	Arithmetic's	336 (5.76%)
Math Reasoning (MR)	Comparison	213 (3.65%)
	Correspondence	146 (2.50%)
	Sets	115 (1.97%)
	Ordering	131 (2.25%)

Four small pre-schools with total 133 students (average 33.25, male and female both) were selected. Children age ranged between 4 to 6 years (average 5.2). Each class is led by one female teacher for the whole day. The children worked both with the routine practices and the proposed application (CogSkills) installed on the touch screen mobile phones. All of the students were provided with an Android-based mobile phone for a short period of time during their school timing. CogSkills is the only application installed on all provided mobile phones. The teacher had created profile for every individual student on the allocated mobile phone during the first time use of the CogSkills. After daily usage, the mobile phones were taken back from the children. The school has the facility of the internet. During and after every usage, the application updates the student profile to an online server using internet. Consent of agreement from the parents of the children had also been taken to involve them in the experiment too. Parents of 94 children already own Android-based mobile phones. CogSkills was installed on their mobile phones as well for their child to use at home. Parents are allowed to install any other application of their choice along with CogSkills. The student profile is synchronized back with the online server from home by using internet or 3G connection provided for the period of time during experiment. The rest of the 39 students from experimental group use CogSkills only at school for designated time frame.

The correctness of CogSkills was validated by evaluating the auto-generated contents during experiment by CogSkills against all user profiles. Information of these auto-generated contents was stored in the logs recorded and updated on online server by the CogSkills. Initially fifteen contents were hardcoded within CogSkills as a starting point. Solution of each content was entered randomly (correct, incorrect, partial correct) in CogSkills so that it progress further. CogSkills progresses further based on results of student's previous solutions. Since there is no sophisticated assessment model yet in CogSkills but the use of semantic knowledge modeled with-in ontologies is working. The experiment continues for 15 working days. The average playtime of all the children for 15 days is 153 hours (Std. Dev. 0.56). This playtime is calculated by adding only the active state of a student with CogSkills. The states in which the CogSkills is running but no action was performed for 10 minutes were not considered. The sum of average number of contents per day is 2031 (Std. Dev. 7.47). Table-2 shows total number of dynamically created cognitive skills contents under WPPSI and WIAT-II categorization. Classification contents mainly generated through classification defined among concepts of ontologies. Classification contents under information (IN) category contain contents those require classification based on implicit characteristics e.g. "living and non-living things". Similarly classification contents under picture concept (PCn) are the contents that require physical classification e.g. "Big objects Small Objects", "Animal and Plants" etc. Relatedness contents are generated through either direct or indirect relationship present between concepts or inferred by the reasoner. The contents generated through indirect relationships (symmetric, inverse, transitive etc) and inferred by the reasoner engine provide a positive indication toward CogSkills potential benefits. Similarly comparison contents contain all those objects that are subclass of or associated with measureable concept in cognitive skills ontology. Disambiguation contents are generated by selecting concepts of two different classifications. Similarly concepts of different relatedness but having some common classification are used to produce contents under correspondence math skill e.g. "4 Cups and 4 Saucers", "1 plate with 1 fork and 1 spoon" etc. Ordering is based on common property among different objects. Example of ordering is shown in Figure-3.

CONCLUSIONS

In the present paper, a conceptual framework (MySekolah) was constructed that provides a guidelines for the designing and evaluation of the preschool cognitive skills learning through the use of tutoring system based on semantic web technologies (knowledge base) supporting both the instructional and the constructive pedagogies. The conceptual framework is the unification of the expert systems components, the pedagogical approaches and features of the semantic web technologies. The components of the MySekolah address the overall construction of a tutoring system based on ontologies as domain and student models, implementation of pedagogical issues such as constructivism and curriculum sequencing. Assessment model as component of the MySekolah guide about individualized learning based on child understanding. Finally the interface or the content presentation model deals with the user interactions.

The present work has laid a foundation for application of Semantic Web technologies in the real life scenario. The research can be applied and extended in future to several other possible domains. The present research is applicable in the semantic search engines development. Where generic knowledge is required to be extracted from the web of data. Similarly the idea of creating internet of things (IoT) can take benefit from the present research as in IoT everything of the real world need to be uniquely identified and communicate with other things. The current research not only addresses the cognitive skills rather it can be extended to support intelligence quotient (IQ) evaluation and basic language learning. Higher levels of education than preschool such as kindergarten can a possible scenario for the present research.

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