The Multimedia-Based Learning System Improved Cognitive Skills and Motivation of Disabled Children with a Very High Rate

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ABSTRACT

A multimedia-based learning system to teach children with intellectual disabilities (ID) the basic living and science concepts is proposed. The tutorials' development is pedagogically based on Mayer's Cognitive Theory of Multimedia Learning combined with Skinner's Operant Conditioning Model. Two types of tutorials are proposed. In the first type; the contents are developed in a static manner while in the second type; the contents are developed using a domain-specific ontology with text processing tools and Google search engine. Both types of tutorials have shown a considerable improvement in the learning process and allowed the children with ID to improve their cognitive skills and become more proactive in the classroom.

Keywords

Multimedia Tutorials, Learning Model, Intellectual Disability, Ontology

Introduction

Children with intellectual disabilities (ID) are very challenging to teach, and can learn best with the use of different methodologies that engage their senses, such as using images, sounds and clips. In fact, every child in the same classroom may have a different way of understanding, and should have an individual learning plan with specific goals and objectives. Therefore, instructors use different methods to teach these children in an acceptable manner (Adam & Tatnall, 2008).

Existing research in Universal Accessibility (UA) related to individuals with ID is quite limited. Studies that examine cognitive disabilities started to emerge only in the past decade. Cohone et al. (2007)worked on developing reminiscence tools for people with Alzheimer's disease. Wu et al. (2007) developed some tools for people with amnesia. Moffatt et al. (2004) developed tools for people with aphasia. A field that has drawn increasing attention both in the general public and in academia is the study of children with autism and the attempt to improve their language development and social skills via computer mediated software or agents e.g., Lehman (1998), Hart (2005), and Tartaro & Cassell (2008). In addition to developing technologies to be used by children with autism themselves, researchers also explored technologies to assist the children's caregivers in communication, record collection and analysis, decision-making, and assessment of the children's internal states as what was done by Kientz et al. (2007). A few studies investigated people with ID together with users of various other cognitive impairments e.g., Dawe (2006). These studies provide valuable insights regarding the impact of cognitive impairments on the use of computer-related activities. But due to fundamental differences between conditions such as Alzheimer's disease, amnesia, aphasia, Autism, and ID, observations and findings from these studies cannot be readily applied to children with ID.

Researchers in special education are to some extent informed of the potential of computer technology in helping individuals with ID, e.g., Buckley (2000) and Black & Wood (2003). They claim that computer technology can help people with ID increase confidence and motivation through creative activities and web browsing. Computer technology also has other benefits, including errorless learning, patient feedback, immediate feedback, self-paced learning, and independence of learning. However, Lloyd et al. (2006)suggested that the actual benefits of computer technology may be reduced or not apparent depending on the quality of the software. First, the contents of many software programs are not age appropriate. Second, many educational software are unable to reach educational goals and are used as a tool for mere entertainment. Third, many applications do not promote independent learning.

Different approaches have been proposed to present the multimedia-based learning system (Adam & Tatnall, 2008; Evans et al., 2006; Garcia-Ruiz et al., 2008; Kirk et al., 2011). The empirical study conducted by Ortega-Tudela &

Gómez-Ariza (2006) examined the impact of educational software on learning mathematical counting skills. Eighteen children with ID have participated in the study. Ten of them used multimedia education software to learn basic counting skills and the other eight tried to learn the same counting skills via the traditional paper-and-pencil approach. After fifteen sessions, children who used the educational software demonstrated significantly higher performance than those who used paper and pencil. Wuang et al. (2011) illustrated a system that applies design and learning theories in developing multimedia courseware. This system develops multimedia courseware of Loci in two dimensions (Li2D) using ADDIE methodology with Macromedia Flash 8 and Adobe Photoshop. The theories that have been applied in the development include: Design Theory, Behaviorism, Constructivism, Cognitive and Van Hiele Thinking Model. A Computer Reinforced Online Multimedia Education (Crome) framework was proposed in (Dong & Li, 2006). The authors presented a method to integrate main components of learning, teaching, testing and adaptive student modeling. Crome was designed to incorporate portability, reusability, scalability and interoperability. Cheng et al. (2009), proposed a multi-ontology based multimedia annotation model in order to ensure effective utilization of multimedia by different users. In this model, domain independent multimedia ontology, based on MPEG-7 content description tools, was integrated with multiple domain ontologies to provide multiple domain-specific views of multimedia content. A term extraction procedure was designed to automatically extract domain specific ontological terms from textual sources. Evaluation results prove that multi-ontology based multimedia annotation enhances various users' information needs.

Although there is little research on computer usage of individuals with ID, there is one well-documented design case for this population. The National Down Syndrome Society (NDSS, 2009) worked with a Web design firm to develop a Web site specifically designed for people with ID, called Web Fun Central. The goal was to teach Web browsing and other computer skills specifically. Six individuals with ID became part of the design team and took part in usability testing sessions. Two separate usability tests, both involving the same six participants, were completed to inform the design. As a part of this process, the researchers were able to develop a number of guidelines for designing Web sites and computer-based learning modules for people with ID.

In this work, we propose an assistive educational system using multimedia technology to teach the children with ID the basic concepts of daily living tasks and elementary sciences in an attractive way. Such a system is highly needed due to the lack of appropriate contents for children with ID in the state of Qatar. Our proposal generates the multimedia tutorials which can be easily used by the instructor and provide mentally disabled children the opportunity to learn with tutorials designed to suit their intellectual needs. We use a combination model of two cognitive theories, as is elaborated in section 2. The development of the tutorials is based on two techniques; the static manner is presented in section 3, and the dynamic technique in section 4. Assessment and analysis is presented in section 5. The last section concludes the paper.

Learning models

Both types of proposed tutorials, dynamic and static are developed with a combination view of two cognitive models: Mayer's Cognitive Theory of Multimedia Learning which implements using multimedia elements to enhance the learning experience of a child, and a mild implementation of Skinner's Operant Conditioning which suggests using gentle positive and negative reinforcements to help motivate the child.

Mayer's cognitive theory of multimedia learning

Mayer's Cognitive Theory of Multimedia Learning (Mayer & Alexander, 2011) allows children to use their auditory and visual channels in the learning process. It involves active use of their sensory, working and long-term memory to process multimedia elements into logical mental constructs. This theory assumes the following:
- There are two main channels for processing information; auditory and visual.
- Each channel has a finite capacity for cognitive load.
- Filtering, selecting, organizing and integrating information is an active part of the learning process.

According to Mayer, there are three important cognitive processes, which the multimedia learner engages in. The first one involves selecting verbal and visual information to yield a learning base, the second involves organizing verbal and visual information to form into coherent mental representations, and the third one includes integrating the

resulting verbal and visual representations with one another. The following figure represents this cognitive process (figure 1).
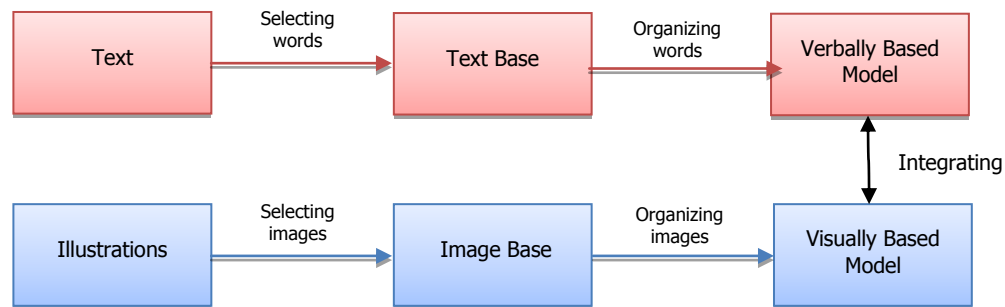

Figure 1. Cognitive process of multimedia model

Skinner's behaviorist operant conditioning model

Skinner's Behaviorist Operant Conditioning Model (Staddon & Cerutti, 2003) is a process that encourages behavior through positive or negative reinforcement. Reinforcement may come in the following forms:
• Positive reinforcement: favorable event given to a child after an achievement (praise, reward, etc.).
• Negative reinforcement: the removal of an undesired outcome after a positive achievement is made by the child.
• Positive punishment: unfavorable event is given in order to weaken the following response.
• Negative punishment: favorable event is removed after undesired behavior occurs.

According to Skinner, there are three types of responses that can alter behavior:
• Neutral operants, which are responses from the environment or other unaffecting factors, which neither increase nor decrease the probability of a certain behavior happening.
• Reinforcers, which are responses that increase the probability of a certain behavior being repeated. These reinforcers may be positive or negative.
• Punishers, which are responses that decrease the likelihood of a certain behavior being repeated.

While Skinner's theory implies that human behavior is solely affected by external factors such as what the subject is being exposed to, we note that external factors merely play a role in the child psychology and learning process, and the ideology of Behaviorism may be integrated with other techniques which do take into account internal factors such as thinking, emotions and previous experience. For the purpose of this study, only the positive and negative reinforcement will be mildly used, and this is in order to promote positive encouragement of the child rather than negative.

Static technique

The static technique consists of setting first the lessons objectives and contents with the assistance of the special education instructors. Our system supports and monitors the learning process through providing several interactive educational multimedia contents consisting of text, images, and short clips. These multimedia elements are linked to the objectives of teaching personalized plan. The system can be used in two ways:
• Group activities: The system uses a smart board to view multimedia contents, i.e. lessons, puzzles, quizzes, etc. The children can interact with these contents.
• Individual activities: each child has his own tablet. The teacher controls the class by sending different multimedia contents to the children's tablets according to their level of abilities and personalized teaching plan. The children are able to practice the contents at home as the teacher will daily transfer a copy of these contents to the children's tablets.

The users of the system

The system has four types, which are: administrator, teacher, student, and parent.
- Administrator: It is the responsibility of the administrator to manage all users' accounts including adding deleting, and updating. He/she uploads the multimedia contents and the plans. He/She links these contents with their corresponding objectives. System settings like sending parents periodic SMS/Email for feedback on their children progress are also handled by the administrator.
- Teacher: The learning process in the class is managed by the teacher who can control the educational multimedia contents to be viewed on the smart board as well as the students PC tablets. The teacher also transfers the daily covered contents of each student to his/her tablet for home revision with the parents.
- Student: This is the main user of the system who can smoothly interact with the contents available on both class smart board and PC tablet. Upon completion of a lesson, the system provides the student with several puzzles and games to evaluate his/her understanding of that lesson. This process is done with multiple trials, and intelligent algorithms are built to indicate student's mistakes. The system tracks all student results, records it in database and eventually reports the student performance.
- Parent: The system effectively contributes in increasing the level of interaction between the parents and their children through: First, sending periodic short SMS and Emails about the children progress. Second, ability of accessing the system website to post feedbacks about their children personalized plan. Third, having the class materials installed on the children PC tablet gives the parent the opportunity to follow up with their children's daily classes. Finally, parents can review their children's daily lessons and contact teachers for any inquiries.

Educational content

The system provides a large number of contents to meet the objectives of the learning process for the children. These contents are designed and customized based on the international educational system FACE curriculum, which is widely used to teach children with special needs and it covers different scopes including math, science, reading, writing, religion, and social life. The contents are designed with a focus on:
- Represent the local Qatari environment such as dress, food, shops and currency.
- Suit students' intellectual, vision, and hearing capabilities (i.e., levels of difficulty, sounds, and Developed color).
- Interacts easily with students to achieve the learning objectives.
- Motivates students through employing exciting contents as opposed to rigid teaching.
- Varies in teaching styles (i.e. multiple choices, match objects, drag and drop, find similarities, and puzzles).
- Features the ability to repeatedly update, improve, and personalize contents. Organized and sequenced logically i.e. from easy to difficult, and basic to advanced.
- Organized and sequenced logically i.e. from basic to advanced.

Next the characters and the different scenarios are reviewed by special education instructors in order to achieve high quality tutorials. Then, the lessons are designed with the help of a graphic designer and multimedia developer. Finally, we add the animations and the corresponding sounds using the standard Arabic language, which are recorded in a studio. Final tutorials are stored in a specific database and can be used incrementally according to the children's performances. Every tutorial needs approximately three months in average to be completed properly. Our multimedia tutorials are developed using Adobe Flash CS3, and Action Script. They consist of high quality animations at a video frame rate of 32 frames per minute. All lessons are taught in Arabic with the use of multimedia tools that appear attractive to children. Figure 2 shows some snapshots from the static tutorials.

Figure 2. Snapshots from the static tutorial content

Dynamic technique

In the second technique, we propose to generate multimedia tutorials dynamically through providing an automatic mechanism to query for a desired topic based on semantic content analysis and ontology. The instructor can easily customize the tutorials based on the specific needs of each child in the classroom. The dynamic tutorials would become more time efficient due to the machine learning process of the automated system. The system will statistically learn the preferred customization per student and will generate automatically customized tutorials.

Figure 3 gives an overview of the different steps of our proposed system. The first input is the educational text that will be processed using text-processing tools (i.e., segmentation, stemming, analyzing). We parse text with the Stanford Parser that aids to retrieve sentences containing pairs of keyword entities and represents them by using a data structure called a "Dependency Graph" (Klein & Manning, 2003). The objective is to identify the actors (i.e., lion, elephant, tiger), the objects (i.e., water, plant), and the actions (i.e., attack, live, eat) in the story text. Each retrieved sentence is analyzed to extract the raw relationships between keywords entities. The extracted relationships and entities will be semantically mapped and validated according to the domain description captured in an ontology model. All raw relationship instances are sent as semantic queries in order to retrieve the available multimedia instances in our ontology (i.e., the knowledgebase). Complimentary queries will sent also to the Google image database through Google APIs to fetch the corresponding multimedia elements. Hence, the teachers can then select the appropriate multimedia elements that are suitable to customize the tutorial based on the needs of each child in the classroom.
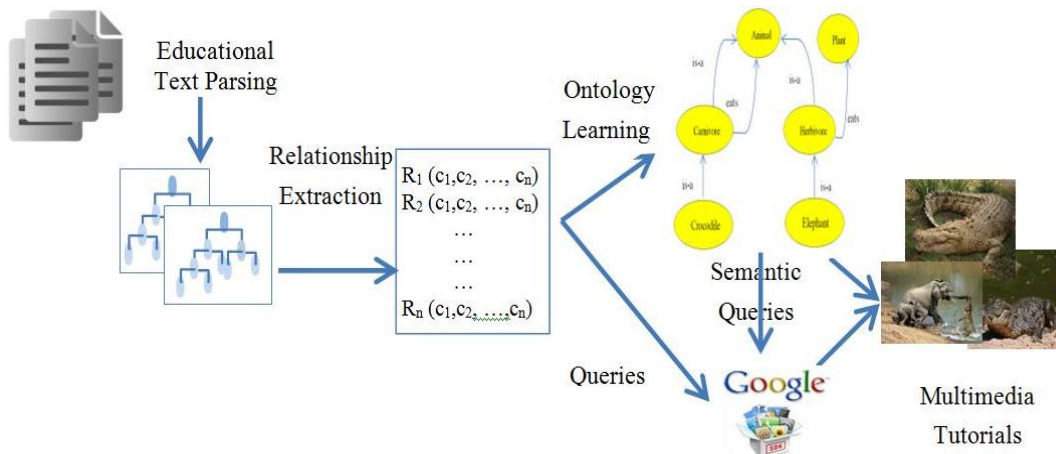

Figure 3. An overview of educational text analysis method

Educational Text Parsing and Semantic Relations Extraction

In this step, the text input is segmented into sentences. Each sentence will be processed syntactically to recognize its part of speech. The goal is to provide the syntactical structure of educational text sentences. The word that belongs to a verb or a noun grammar category is defined as an entity. We focus on sentences that mention at least two keywords entities. The parser returns "parse trees" which is a rooted tree. Each node in the tree represents a part of the sentence, as in Figure 4. The parse trees generate by using the Stanford Parser that is a statistical natural language parser (Sleator & Temperley, 1995). It uses a set grammatical function of words to record the most likely syntactic structure of a sentence.

We next transformed the parse tree into a Dependency Graph (DG) format (De Marneffe et al., 2006) that we analyze to extract the semantic relationships. The DG captures the implicit dependencies (semantics) between keywords and entities in a sentence. Each node is a word and labeled edges represent grammatical relations between words. DGs are rooted, oriented, and labeled graphs that make them easier to read and process than parse trees or other representations.
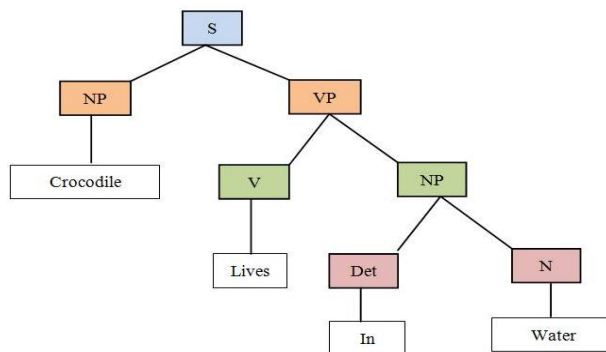
Figure 4. Sample parse tree of the sentence "crocodile lives in water"

Therefore, we extract the semantic relations in a subject-predicate-object triplet form, corresponding to the RDF statements (Klyne & Carroll, 2006). Subjects and objects represent words entities. Predicates are used to describe the nature of the relationship between two entities with a sequence of words. In order to realize a good extraction, we use a set of grammatical patterns that express relations between entities. These deep dependencies linguistic analysis of sentences will be perform by using the grammatical formalism called link grammar (Sleator & Temperley, 1995). In this formalism, the links are labeled depending on the nature of the grammatical relationship of two terms within the sentence. For example, the link label **"S"** is used to connect a subject to a verb, while **"D"** is used to connect a determiner to a noun. If the terms are not directly connected, one of the properties of the formalism, called connectivity, ensures that all terms of the sentence are at least indirectly connected via a number of intermediary terms. A path between two words of a sentence is called a link-path. The source and target of a link-path are denoted as start term and end term respectively. The set of all links describes the grammar of the entire sentence is referred to as linkage. The sequence of words interlinked on that path is called word-path and it can be seen as the semantic relationship between two terms.
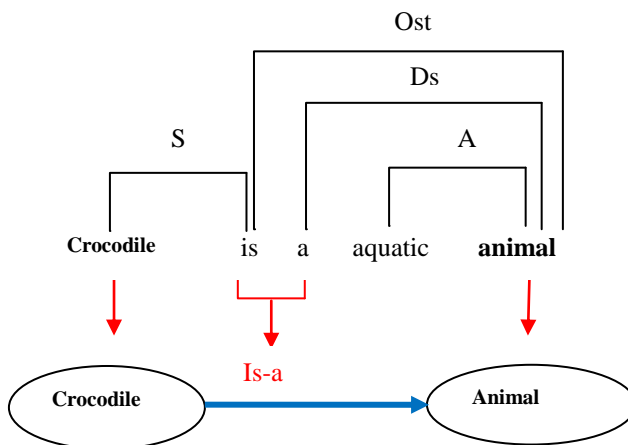

Figure 5. Relation extraction from sentence "Crocodile is an aquatic animal"

Given the sentence "Crocodile is an aquatic animal ". The individual terms of the chain are listed as follow:

- Start-term: "Crocodile"
- Stop-term: "Animal"
- Word-path: "is," "an"
- Link-path: "Ss, Ost, Ds, A"

Figure 5 illustrates the linkage of the example sentence. The connected terms used in the example is highlighted. The word-path describes the relation between start and stop term. By combining the terms in the word-path to form a single predicate, the valid semantic relation Is-a (crocodile, animal) is generated.

For finding a set of valid link-paths, we propose manually annotating a set of semantic relation triplets. The table shows grammatically distinct types of predicates can be found by using predefined link-paths. The link-path such as (LiveIn) uses the information given by two terms that function as subject and object to a verb. We can use it as predicate LiveIn(crocodile,   tropics). While in the case of the link-path (is-a), we have two nouns which are connected with a predicate, as we have seen is the previous example of Figure 5.

Table 1. Link-paths and Predicates

Link-path	Predicate
Ss Ost Ds	Is-a
Ss Ds	LiveIn
Ss PvMvJp	WasAttackedBy

Ontology learning development

Since ontologies provide a shared understanding of a domain of interest, they have become a key technology for semantics knowledge extraction and integration. The aim of ontology is to develop knowledge representation that can be shared and reused. Guber (Gruber, 1995) defined ontology as: "A formal explicit specification of a shared conceptualization." Domain ontology provides particular meaning of terms as they apply to that domain. In our system, the use of ontology can provide a common underlying language that aids to understand the extracted knowledge from different educational texts. Ontology can help to provide semantic concepts that we can use for searching and retrieving the multimedia elements to build the tutorials.

Therefore, we write down in an unstructured list all relevant terms that are expected to appear in the ontology and we would like to provide an index of specific children's tutorial (animal, food, etc.). For animal ontology as an example, we could make the following questions to extract the most important animal-related terms. Where they live? What they eat? How dangerous they are? And a bit about of the basic anatomy (number of legs, wings, toes, etc.). Therefore, the terms list will be include: animal, subtypes of animal (herbivore, carnivore), different names of animal (i.e., crocodile, elephant, tiger, bird, etc.), location, plant, water, animal actions (i.e. eat, attack, etc.), and so on.

For developing the concept hierarchy, we usually start with the definition of the most general concepts in the domain and subsequent specialization of the concepts. From the list created previously, we select a group of animal-related terms and ask what they have in common and what "siblings" there might be. Hence, we specialize the animal class by creating some of its subclasses such as (herbivore, carnivore). We can further categorize the carnivore class into (crocodile, tiger, lion), and so on. These concepts will be arranged in a hierarchical taxonomy to form the ontology. All the siblings in the concept hierarchy must be at the same level of generality. The concepts alone will not provide enough information to answer all the questions about the animals. Once we have defined some of the concepts, we must describe the internal structure of concepts. For example, Animal parentOf animal, elephants eat planets.

The underlying formalism for ontology is Description Logics (DLs) (Baader & Nutt, 2003), which are a family of knowledge representation formalisms that have formal semantics. This family of logics is tailored towards representing terminological knowledge of an application domain in a structured and formally way. Description logics allow users to define important notions, such as classes or relations of their application domain in terms of concepts and roles. These concepts (unary predicates) and roles (binary predicates) then restrict the way these classes and relations are interpreted. Based on these definitions, implicitly captured knowledge can be inferred from the given descriptions of concepts and roles. These inferences are defined based on the formal semantics of DLs.

The central notion for DLs is concept descriptions, which can be built from concept names. For example, one can describe animal ontology in DLs as an Herbivore that eats only Plants as follow:

$$\text{Herbivore} \equiv \text{Animal} \sqcap \forall \text{eats}. \text{Plant}.$$

The last step is creating individual instances of classes in the hierarchy. We use Protégé editor(Protégé, 2007), which is a free, open source ontology editor and a knowledge acquisition system. It is a tool supporting the construction of ontologies and it also provides an application platform for knowledge-based systems. Defining an individual instance of a class requires: (1) choosing a class, (2) creating an individual instance of that class, and (3) filling in the values.
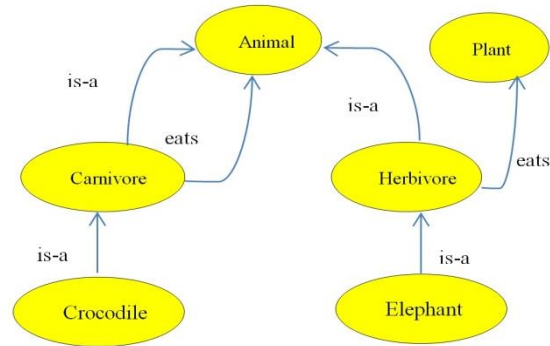
Figure 6. Example of part of animal ontology

After we define an initial version of the ontology, we can evaluate and debug it by using it in applications or by discussing it with experts in the field, or both. As a result, we will almost certainly need to revise the initial ontology. This process of iterative design will likely continue through the entire life cycle of the ontology.

Multimedia tutorial building

Our system applies the mapping process between dependency graphs and our ontologies according to each topic. The extracted relationships and entities will be semantically mapped and validated according to the domain description captured in an ontology model. Thus, we need to leverage the degree of the similarity between text-extracted entities that correspond to the nodes in the dependency graph and the concepts in the ontology (called concept entity). Once, we find an instance match for the subject and the object. We search to find a matching property for the predicate in the domain ontology model. Finally, we check if the concepts to which the instances for subject and predicate are asserted in domain and range of the property matched.

After determining the mapping concepts, we can combine them into semantic queries in order to retrieve the corresponding multimedia instances. A query language such as SPARQL seems to be best appropriate tool (http://www.w3.org/TR/rdf-sparql-query). SPARQL is particularly adequate for extracting data from ontology and through its construct statement, we can generate new data. The SPARQL query is executed against the knowledge base, which returns a list of instances that satisfy the query. Then the multimedia instances that are retrieved, ranked, and presented to the instructor. Complimentary queries will sent also to the Google image and video database through Google APIs to fetch more multimedia elements. Finally, the instructor can then select the appropriate multimedia elements that are suitable to the needs of the children in the classroom. Teachers can get additional multimedia elements either from the ontology or from Google search engine by simply clicking on the words or sentences of the text. Figure 7 shows the retrieved multimedia elements corresponding to the following educational text: "Crocodile is a aquatic animal that lives in the tropics in Africa. Crocodiles attack the elephants."

Figure 7. Multimedia elements associated with the educational texts

Assessments

The proposed learning systems have been tested on 100 children with ID from the Shafallah Center in Doha. The children have an average mental age of 8 years, and are mildly disabled. Half of these children have Down syndrome

(DS), and the other half have various intellectual disabilities (ID). The selected children have some basic ability of reading simple Arabic words, doing simple calculations, recognizing and pointing to objects. Twenty special education instructors from the Shafallah Center participated in the assessment to assist the children using in the learning sessions. A training session was conducted for these teachers to explain to them how to use the system along with the tutorials and the exercises.

The children are first allocated to try the static multimedia tutorials, and are subjected to corresponding exercises that indicate their comprehensive understanding level of the lessons. Their performance scores are assessed by their usual instructors according to an assessment model developed for this testing session. Next, the children are allocated to test the dynamically generated multimedia tutorials on a different set of lessons, but in a similar level of difficulty. The dynamic method involves the instructors teaching the lessons in the conventional story book method, and then reinforcing the concepts by dynamically extracting multimedia elements that correspond to the lesson, using the developed system. The children's knowledge is then tested using a set of exercises, and their performance scores are assessed once more by their instructors by using a pre-developed assessment model. In addition to gathering performance score information, we have developed an assessment rubric to measure motivational levels of the children. The motivation assessment rubric consists of scoring the relative motivation level of each child, as observed by its regular special needs instructors. The scoring method involves a motivation spectrum measure of 1-10, 1 being least motivated, and 10 being most motivated. As an average in Shafallah Center, each group of 5-6 children have one special needs instructor dedicated to their class. Therefore we were able to rely on the special needs instructor to score the relative motivation levels as observed while using multimedia tutorials, static and dynamic.

The children are assessed based on a scoring system that takes into account the following constraints: physical age, mental age, disability, gender, timing, number of correct answers, number of repetitions required to understand the lesson, mood and motivation of child, and exceptional hardships. The obtained results indicate the following about both dynamic and static models: increased motivation, improved performance, relatively speedy learning and improved memory function and memorization.

The assessment process is divided into three parts: static tutorial assessment, dynamic tutorial assessment and combination assessment.

Static Tutorial Assessment

Static assessment consists of evaluating the average performance scores, timing, and motivation levels. Results are differentiated between children with DS and other IDs, and females versus males. Figure 8 depicts results in terms of percentile scores, relative timing and motivation levels observed, comparing the results of the children with ID with the children with other DS. Note that the time depicted here represents the average time (in minutes) that each student took to complete an exercise. As shown in the graph, we can see that children with ID and DS both scored high average scores ranging from 70% to 80%, although we note that the children with DS slightly outperform the ones with other IDs. High motivation levels for both groups were also reported with an average of 85% to 90% children exhibiting increased motivation. We can conclude that the implemented multimedia lessons have been equally useful and effective for all groups of disabilities.
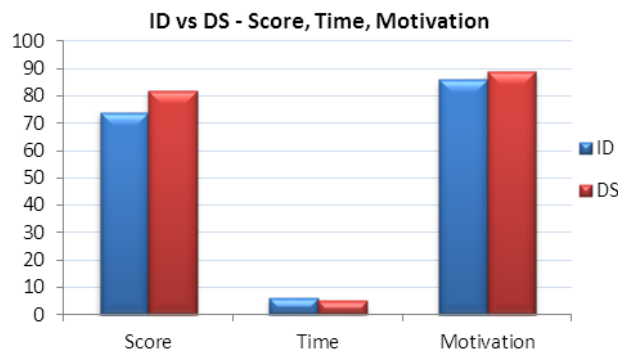

Figure 8. Performance of ID vs DS – Static tutorials

Figure 9 illustrates the performance of females versus males, without taking into consideration differences in disabilities. As shown in the graph, female children have outperformed the male children by a 15% range. The average score of all females is 81%, while the average score for males is 62%. It is worthwhile to note that while the females fared better in terms of scores, the males took less time to complete the exercises, which is indicative of the relative nature of the genders; females tend to be more patient and objective oriented, while males tend to be impatient and view the lessons and exercises as games rather than lesson scores. We can conclude from this graph that the multimedia lessons had better results on females rather than males.
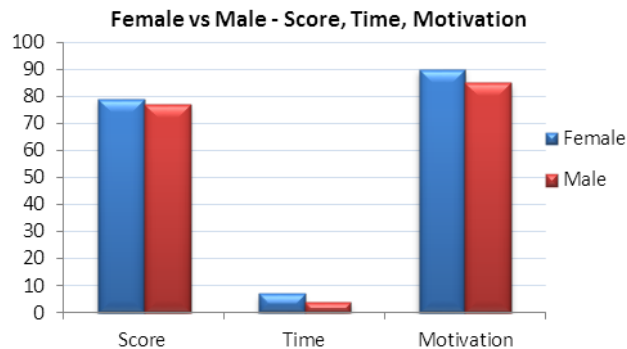

Figure 9. Female vs Male performance – Static tutorials

Dynamic tutorial assessment

Dynamic assessment, similarly to the static assessment, consists of evaluating the average performance scores, timing and motivation levels. Results differentiate between children with DS, ID, females and males. Figure 10 demonstrates results in terms of percentile scores, relative time and motivation levels. Children with DS slightly slightly over performed the children with other ID, scoring within a higher range of 10%. Children with other IDs were also noted to have taken a longer amount of time to complete exercises. Both groups exhibited high motivation levels, although the children who scored better (DS) are more likely to have higher motivation to keep trying.
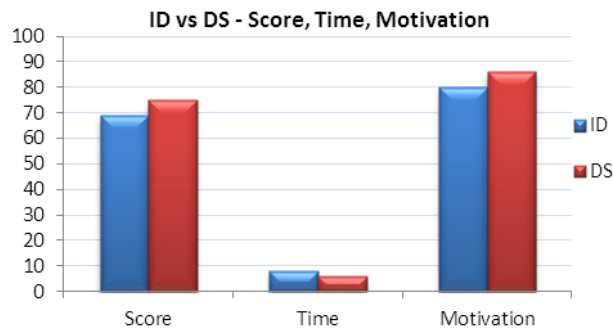

Figure 10. Performance of ID vs DS – Dynamic tutorials

Figure 11 depicts the performance results of females versus males, regardless of disability differences. We can observe from the graph females outperformed males within a 15% margin, but similarly to the static tutorial results, we notice that females take more time to answer exercises. Dynamic tutorials are more difficult to precisely assess given the time constraint, due to the process of the student first studying the concept in conventional classroom methods, then using dynamic tutorials to back it up. Some students had some difficulties tying the classroom concept with the multimedia concept, as this method is still novel to them. Females exhibited higher motivation levels than males.
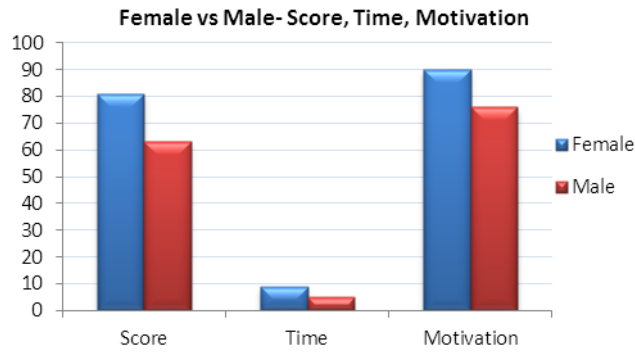
Figure 11. Performance of females vs males - Dynamic tutorials

Combined assessment

The combined assessment consists of the evaluation of both static and dynamic systems in combination and comparison to each other. Figure 12 depicts the acceptance and relative performance levels of all the children. 7.5% of the children tested with the static tutorials refused to accept or participate in the lessons, due to some physical stress they received from the sounds associated with the lessons. 2.5% participated but found it too difficult. For the dynamic tutorials, we have a slightly higher acceptance rate, as only 5% of students rejected participation and another 5% found the concept of linking the lessons with the multimedia elements too difficult. Relative performance levels significantly increased, when compared to the performance of the children at conventional lessons, without the use of multimedia. 88% of the children exhibited higher relative performance with the static tutorials, and 82% had higher performance levels with the dynamic tutorials.
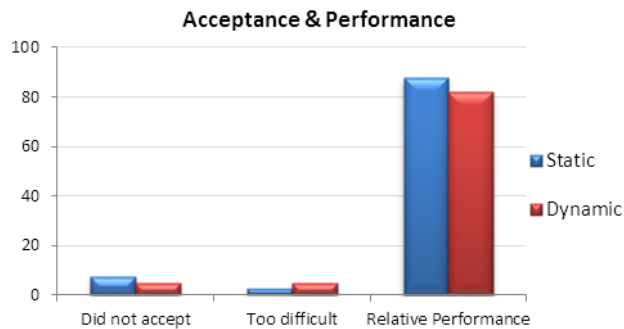

Figure 12. Acceptance and Performance of children

While statically generated tutorials have proven to be a good source of education for the children with IDs, allowing for increased cognitive levels, motivation, enthusiasm and high relative performance levels, the problem faced with these pre-designed tutorials is the time consumed to generate each. Each tutorial, designed as per the specific curriculum specifications for each class or school, requires one month of work by animation, script and sound studio experts. Whereas, the benefit behind dynamically generated tutorials is to be able to generate a customized tutorial on the spot, in the classroom, with no predesigning requirements. Furthermore, the instructors can chose multimedia elements to complement the lessons and can customize each tutorial combination for each student as seen fit. Testing with the dynamic tutorial generation has proven to be similarly as effective for the children with ID, has increased cognitive levels, motivation levels and relative performance levels. Figure 13 illustrates the average timing required by the instructors to generate each dynamic customized tutorial in the class time. As shown in the graph, 21% of trails required 6 minutes to generate a tutorial, 47% took 10 minutes, and the remaining needed an average of 15 minutes or more.

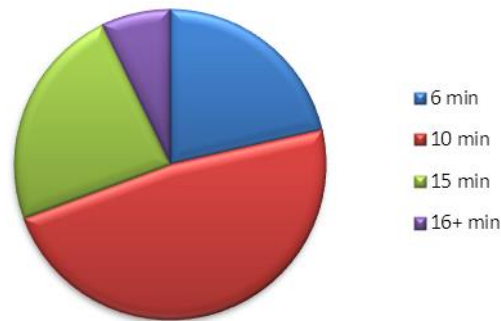**Time to Generate Customized Tutorial**

Figure 13. Average time required to generate dynamic customized tutorials

Table 2 below demonstrates a summary of average score, motivation and timing levels achieved by the students per static and dynamic tutorials.

Table 2. Summary Scores

	Static	Dynamic
ID	Score: 74% Motivation: 86% Time: 6 min	Score: 69% Motivation: 80% Time: 8 min
DS	Score: 82% Motivation: 89% Time: 5 min	Score: 75% Motivation: 86% Time: 6 min
Female	Score: 79% Motivation: 90% Time: 7 min	Score: 81% Motivation: 90% Time: 9 min
Male	Score: 77% Motivation: 85% Time: 4 min	Score: 63% Motivation: 76% Time: 5 min

In an overview of the assessment results, it can be noted that children with DS seemed to achieve better results than that of children with other IDs, and females, while taking more time achieve better scores due to their detail oriented nature, whereas the boys tend to deal with the multimedia tutorials in a more playful manner. Nonetheless, all groups obtained high scores, and teachers noted an 80% - 88% increased relative performance in their students after having used either the static or dynamic tutorials. Instructors were enthusiastic about using the system in the classroom as part of daily lessons and noted the numerous benefits on the children's part; including higher motivation levels, increased performance, faster cognition and high acceptance rates.

The limitation of our assessment was not testing out the differences in performance between static and dynamic tutorials, over prolonged periods of time. We were allocated one week of testing for the static tutorials, and one week of testing for the dynamic tutorials. The reason the time factor is so important because we hypothesize that the longer dynamic tutorials are used, the more effective they will be. However, being tested only over a period of one week does not allow us to gather a complete picture. The dynamic tutorials have to be used in accordance with conventional classroom methods, so the instructor would first introduce a concept in class, and then enforce the understanding of the concept with related tutorials. As a first trail for the children, some students faced some difficulties tying the two classroom concept with the multimedia concept. We predict that with further use results will be far improved. On the other hand, this assessment had various strengths: the number of children allocated to testing (100), having both genders tested, and having several types of IDs allows us to further understand how to target each group. Having the cooperation and dedication of the special need instructors of Shafallah Center was also an incredible strength to this assessment, as it could not have been done without their expertise.

Conclusions

This work proposed a novel assistive educational system to generate multimedia-based tutorials under a combinational pedagogical model: Mayer's Cognitive Theory of Multimedia Learning and a mild implementation of Skinner's Operant Conditioning model. The system is implemented in two main methods: (1) pre-designed or "Static Tutorials" where which tutorials are custom designed by animation experts according to specific curriculum needs and (2) "Dynamic Tutorials," where which the following techniques are used to generate customized tutorials: text processing, relationship extraction, ontology building and dynamic extraction of online multimedia elements. The dynamic tutorials system allows instructors to generate tutorials on the fly, in the classroom, and in accordance to the lesson they are teaching. Instructors can choose multimedia elements appropriate for the specific needs of the child they are teaching, within minutes. The noted advantage of using the dynamically generated tutorial system over the statically pre-designed ones, is the amount of time and efficiency saved. The pre-designed tutorials require detailed lesson design by experts, and each tutorial requires up to one month of work. Whereas the dynamic tutorial system, once developed, requires minutes of time for the instructor to generate, and is far more flexible and practical, as it can incorporate many different lessons and does not have pertain to a set curriculum.

From the performance aspect, it has been observed that both static and dynamic tutorials had excellent results on the cognitive ability of the children with ID, allowing them enhanced learning, higher relative performance, higher scores, acceptance and motivation levels. The children exhibited an average score between 70% - 80% and even higher motivation levels ranging from 80% - 90%. In conclusion, the use of multimedia-enhanced learning has been found to be extremely beneficial for children with ID, as well as practical and efficient for their instructors.

Acknowledgments

References

Adam, T., & Tatnall, A. (2008). Using ICT to improve the education of students with learning disabilities. *Learning to Live in the Knowledge Society* (pp. 63-70). doi: 10.1007/978-0-387-09729-9_8

Baader, F., & Nutt, W. (2003). *Basic description logics.* Retrieved from http://osm7.cs.byu.edu/CS751R/DLHandbook.Ch2.pdf

Black, B., & Wood, A. (2003). Utilising information communication technology to assist the education of individuals with Down syndrome. *Down Syndrome Issues and Information.* doi: 10.3104/9781903806296

Buckley, F. (2000). *Assisting Individuals with Down Syndrome to Access Information Technology: An Overview.* Hampshire, UK: DSE Enterprises.

Cheng, I., Basu, A., & Goebel, R. (2009). Interactive multimedia for adaptive online education. *MultiMedia, IEEE, 16*(1), 16-25.

Cohene, T., Baecker, R., Marziali, E., & Mindy, S. (2007). Memories of a life: A design case study for Alzheimer's disease. Retrieved from http://ron.taglab.ca/papers/B14.pdf

Dawe, M. (2006). *Desperately seeking simplicity: how young adults with cognitive disabilities and their families adopt assistive technologies.* Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. doi: 10.1145/1124772.1124943

De Marneffe, M.-C., MacCartney, B., & Manning, C. D. (2006). *Generating typed dependency parses from phrase structure parses.* Retrieved from http://nlp.stanford.edu/~wcmac/papers/td-lrec06.pdf

Dong, A., & Li, H. (2006). Multi-ontology based multimedia annotation for domain-specific information retrieval. *Proceedings of the Sensor Networks, Ubiquitous, and Trustworthy Computing.* doi: 10.1109/SUTC.2006.94

Evans, D. G., Bowick, L., Johnson, M., & Blenkhorn, P. (2006). Using iconicity to evaluate symbol use. *Computers Helping People with Special Needs* (pp. 874-881). doi: 10.1007/11788713_127

Garcia-Ruiz, M., El-Seoud, S. A., Edwards, A., AL-JA'AM, J. M., & Aquino-Santos, R. (2008, September). *Integrating the sense of smell in an educational humancomputer interface.* Paper presented at the Interactive Computer Aided Learning conference, Villach, Austria

Gruber, T. R. (1995). Toward principles for the design of ontologies used for knowledge sharing? *International journal of human-computer studies, 43*(5), 907-928.

Hart, M. (2005). *Autism/excel study.* Proceedings of the 7th international ACM SIGACCESS conference on Computers and accessibility (pp. 136-141). doi: 10.1145/1090785.1090811

Kientz, J. A., Hayes, G. R., Westeyn, T. L., Starner, T., & Abowd, G. D. (2007). Pervasive computing and autism: Assisting caregivers of children with special needs. *IEEE Pervasive Computing, 6*(1), 28-35.

Kirk, S., Gallagher, J., Coleman, M. R., & Anastasiow, N. J. (2011). *Educating exceptional children*: Cengage Learning. Belmont, CA: Wadsworth.

Klein, D., & Manning, C. D. (2003). Accurate unlexicalized parsing. *Paper presented at the Proceedings of the 41st Annual Meeting on Association for Computational Linguistics* (pp. Vol. 1, 423-430). doi: 10.3115/1075096.1075150

Klyne, G., & Carroll, J. J. (2006). *Resource description framework (RDF): Concepts and abstract syntax.* Retrieved from http://www.w3.org/TR/2014/REC-rdf11-concepts-20140225/

Lehman, J. F. (1998). Toward the use of speech and natural language technology in intervention for a language-disordered population. *Proceedings of the third international ACM conference on Assistive technologies*. doi: 10.1145/274497.274503.

Lloyd, J., Moni, K., & Jobling, A. (2006). Breaking the hype cycle: Using the computer effectively with learners with intellectual disabilities. *Down Syndrome Research and Practice, 9*(3), 68-74.

Mayer, R. E., & Alexander, P. A. (2011). *Handbook of research on learning and instruction*. New York, NY: Routledge.

Moffatt, K., McGrenere, J., Purves, B., & Klawe, M. (2004). *The participatory design of a sound and image enhanced daily planner for people with aphasia.* Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 407-414). doi: 10.1145/985692.985744

NDSS, N. D. S. S. (2009). http://www.ndss.org/.

Ortega-Tudela, J., & Gómez-Ariza, C. (2006). Computer-assisted teaching and mathematical learning in Down Syndrome children. *Journal of computer assisted learning, 22*(4), 298-307.

Protégé, e. O. (2007). http://protege.stanford.edu/

Sleator, D. D., & Temperley, D. (1995). *Parsing English with a link grammar.* Retrieved from http://arxiv.org/abs/cmp-lg/9508004

Staddon, J., & Cerutti, D. (2003). Operant conditioning. *Annual review of psychology, 54*, 115.

Tartaro, A., & Cassell, J. (2008, June). *Playing with virtual peers: Bootstrapping contingent discourse in children with autism.* Paper presented at the 8th international conference on International conference for the learning sciences,Utrecht, the Netherlands.

Wu, M., Baecker, R., & Richards, B. (2007). Designing a cognitive aid for and with people who have anterograde amnesia. In J. Lazar (Ed.), *Universal usability* (pp. 317–356). West Sussex: Wiley.

Wuang, Y.-P., Chiang, C.-S., Su, C.-Y., & Wang, C.-C. (2011). Effectiveness of virtual reality using Wii gaming technology in children with Down syndrome. *Research in developmental disabilities, 32*(1), 312-321.