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An awareness-raising E-learning approach for children living in a high diabetic population

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Recent epidemiological studies have shown an increased incidence of diabetes worldwide. In United Arab Emirates (UAE), where this study on Emirati children was conducted, over 20% of the population has diabetes. With such a high incidence, there is a need to raise the awareness of the disease in order to reduce the growing number of cases and manage the disease more effectively. This research aims to identify the needs of affected children and proposes a design for an E-learning prototype that can pedagogically raise their awareness and knowledge of the disease. The use of a prototype was chosen in order to validate and refine the usability of the system, and to quickly evaluate user-interface designs without the need for an expensive working model to help refine and develop the system design. The system requirements were identified through a set of interviews with kindergarten teachers, curriculum design experts in UAE, and diabetes nutrition specialists and clinicians. The rationale behind the interview was to identify the optimal age group, describe the appropriate level of the instructional materials and activities, and propose a suitable learning approach that could facilitate and improve diabetes awareness among this age group. The prototype was evaluated by children, teachers, parents (or guardians) and nutrition specialists. We followed a three-stage software development based on a user-informed approach model for stepwise refinement that ranged from prototype to final design. The evaluation results indicate that the proposed computer-supported learning approach can generate positive learning and behavior in children while reducing the time needed to complete awareness tasks when compared to traditional methods; thus making learning more engaging and allowing children to learn at their own pace.

Keywords children living with diabetes, E-learning, game-based learning, Health awareness, health information systems design, learning theories, medical education, medical informatics

INTRODUCTION

Over 220 million people worldwide have diabetes and in 2005, an estimated 1.1 million people died from the disease. Although 80% of diabetes deaths occur in low- and middle-income countries in United Arab Emirates (UAE), a relatively

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wealthy country where this research was conducted, there is an increasing number of people diagnosed with diabetes. In fact, over 20% of the population has diabetes (1). In addition to an interest and desire to promote healthy lifestyles, research in the area of game-based health education strategies was also a motive for this study.

The goal of this research was to investigate the potential of E-learning to support children with diabetes by elevating their awareness and ultimately helping to reduce the number of people developing this chronic disease. Our study was informed by feedback from diabetes nutrition specialists, expert curriculum designers, clinicians and kindergarten teachers as to the best way to facilitate the communication among people with diabetes and their dependents. We also wanted to identify the optimal (target) age group within which to initiate this project, and to promote an enhanced understanding on the part of children, with regards to diabetes.

This work investigates the use of an E-learning system for children, parents (or guardians) and teachers by using various tools including observations, interviews and evaluations. These findings were subsequently analyzed to develop the E-learning prototype. We designed the initial prototype (2) to meet the requirements that had been captured through interviews that showed the need for developing an E-learning system to help children develop a healthier lifestyle and promote healthy food choices, particularly in relation to diabetes. The interview study showed a need to educate children and their caregivers about food categories and identify the different kinds of foods that children prefer to eat. Safe playing guides can help children to protect themselves from danger by developing correct attitudes and behavior with regard to fire and traffic safety. The interview study also showed the need to educate children about the nature of diabetes, how it develops and progresses and the symptoms they need to be aware of.

This research project addresses the challenge of raising the awareness of diabetes and adopting healthier lifestyles among preschool children by using computer-based tools and a game-based learning approach. An E-learning prototype was designed and evaluated to help raise the awareness of children in order to reduce the incidence and minimize the complications (3) of diabetes.

Background

Diabetes is a chronic disease that affects the way the body metabolizes food for energy and growth. Most digested food is broken down into glucose which is the body's basic fuel. After digestion, glucose travels through the bloodstream and enters cells with the help of the insulin which is formed in the pancreas. Normally, the pancreas produces the appropriate amount of insulin to transport glucose from the bloodstream into cells. However, in diabetic people the pancreas either produces little or no insulin; or the cells do not respond to the insulin that is produced. Glucose then builds up in the bloodstream, passes into the urine and exits the body through the urine. As a result, the body eliminates its major source of fuel even as the bloodstream contains large concentrations of glucose.

For clarification, The National Diabetes Information Clearinghouse (NDIC) states that there are three main types of diabetes (4), which are type I, type II and gestational diabetes.

Traditional diabetics awareness methods

Customarily, doctors have educated patients by showing them pictures or diagrams and explaining the disease and the course of treatment to them. These materials could be hard copies such as brochures, booklets or soft copies in the form Web pages, electronic documents, recordings or videos. Some hospitals produce these types of hard copies to distribute to patients to educate them about the disease without including any of the components of an intelligent tutoring system. Other hospitals provide in-house training for patients and staff as well. Health facilities provide formal diabetes education but many patients resist this type of education. The common reasons cited were: living too far from the hospital (5), inability to travel (6) and demanding job or family commitments (7).

E-learning techniques and technologies for diabetics awareness

E-learning is defined as the delivery of a learning, training or education program by electronic means. It involves the use of a computer or electronic device designed to provide training, educational or learning material. In general, E-learning has been found to reduce the cost and time of training and education (8). It can deliver content by asynchronous, self-paced E-learning. Studies have endorsed computer-based education as an effective strategy for transferring knowledge and skill development to patients (9).

Common E-learning delivery methods include (10) traditional computer-assisted instructions and distance learning methods.

- *Computer-assisted instruction* uses computers to facilitate the delivery of stand-alone multimedia packages for learning and teaching. This method can present vital information to any patient. Audio and visual content includes Flash content, embedded Podcasts, video, product and process displays and measurable, interactive testing making E-learning superior to non-interactive educational materials. This method is used in Intelligent Tutoring Systems (i.e. CAL System, DIABLOG and IDEATel),
- *Distance learning or Webinars* use information technologies to simultaneously deliver instruction to learners who are at remote locations eliminating the cost of travel to a central site. Subject experts distribute up-to-date content and facilitate discussion groups by using well-managed educational web-based seminars (examples of existing webinar systems include MPro Care, Diabetes phone, Emminens Service). This method is used in Web-Based Diabetes Advisory Systems (i.e. AIDA, DiasNet, DIABETEX and DEMS (11)) and Telecare/Telemedicine applications (i.e. DIABTel, M2DM and T-IDDM Project) (12). At present, social networks, e.g. Twitter, Facebook, blogs, Second Life virtual worlds, LinkedIn groups and similar Web-based social applications all offer immediate and effective experiences that keep patients connected to vital information. Virtual medical offices and hospitals are used to provide training and to simplify the patient experience. Patients can contribute to the content in social exchange environments: for example, the LibraryThing Medicine Group, MySpace "CURE DiABETES group" run by patients and supporters (13).

There is also growing evidence that emerging information and communication technologies can improve both diabetes care and outcomes. Some of these technologies are Wrist-Watch Glucose Meters (Tura), Facial Expression as an Adaptive Communications Mechanism (14), Global Positioning System Technology and Diabetes Smart/Chip Card (15).

Game-based learning for diabetics

Game-based learning is considered an effective and efficient way to educate users. It is typically based on applications that use multimedia to create attractive learning tools to achieve specific learning goals, outcomes and experiences (16,17). This approach has been used to study learning (18) and selective attention (19) in children, to investigate memory processes in college students (20), to improve neuropsychological parameters in the elderly (21), to improve attention spans in children with attention deficit/hyperactivity disorder (22), to teach database design concepts (23) and to ease the anxiety of children undergoing chemotherapy (24).

Although, much of game-based learning has been focused on advancing scientific knowledge or for therapeutic purposes, some game-based learning systems have been developed for health support, disease management and educational purposes (25). Examples are games that help children with diabetes learn how to manage their disease (12).

Examples of health education video games include the Egg Breeder and Insulot (26). The "Egg Breeder, Detective, Buildup Blocks" (26) is a diabetic awareness game where children learn to breed a diabetic egg by selecting appropriate amounts of glucose, insulin and exercise based on plasma glucose level. The target behavior of this game is diabetes control. "Insulot" is a cellphone diabetes awareness game (26) with a focus on teaching children the relationships between plasma glucose level, insulin dosage and food. "Packy & Marlon" is another diabetic awareness game (12). In this game, the child is portrayed as a character with diabetes and the target is to develop self-management of diabetes among children and adolescents.

Although the previously cited programs are useful, they are targeted toward older children. Thus, there is a lack of ICT enabled solutions that support children in the preschool and kindergarten age group.

Our research targets preschool children who are aged between 3 to 5 years. Studies show that children develop many food attitudes, behaviors and preferences during their preschool years (27). As noted by Kauffer-Christoffe (28), the *"...window of opportunity for prevention is not long...".* Healthy eating habits are essential for the normal development and growth of preschool children and to reduce the incidence of nutrition-related diseases later in life.

Diabetes awareness in UAE

The UAE is believed to have the second highest incidence of diabetes in the world. Even more alarming is the fact that there are not enough health professionals in the region qualified to deal with diabetes. Thus, there is an enormous and vital need not only for "diabetes specialists" but also nutritionists, diabetic educators and other medical practitioners to manage the complications arising from the disease. Many studies have focused on diabetes

mellitus in the UAE (29–38) and almost all show that diabetes is increasing mainly due to obesity and a sedentary lifestyle. In addition, effective E-learning systems that patients could use to educate themselves are lacking. The UAE spent $436 million (1.6 billion UAE Dirham) on diabetes-related treatments in 2007; an enormous cost which could be reduced by creating or using E-learning systems to raise awareness and improve the communication channels between doctors and patients.

This research describes and evaluates an iterative prototype in which the software was developed in three stages. The prototype approach was used as a proof-of-concept to validate and refine the utility and usability of the system. Feedback was used to quickly evaluate user-interface designs without the need for a resource intensive fully operational model.

METHODOLOGY

In this research, a proof-of-concept prototype is presented and evaluated. The goal was to identify children's needs and preferences, and proposes the design of an E-learning prototype that can pedagogically raise the awareness of and knowledge about diabetes. The prototype was evaluated by children, teachers, parents or guardians and nutrition specialists. We followed a three-stage spiral model for step-wise refinement that progressed from prototype to final design, based on a user-informed approach (2,3).

The study and its methodology were subjected to the institutional ethical review processes of the Research Committee of The British University in Dubai, UAE. The research ethics approach we adopted implemented the following steps:

- Informed consent to participate in the study was obtained beforehand from teachers and parents of the children.
- Identities of the all participants were kept anonymous and confidential. No personal information will ever be disclosed or associated with any answer.
- Information captured from participants was used only for the purpose of this research.
- The accuracy and appropriateness of medical and health information used in this research were verified by experts.

Requirement capture

The basic requirements of the system were captured through a set of interviews with kindergarten teachers, curriculum design experts of the taught curriculum in UAE and diabetes nutrition specialists and clinicians. The rationale behind these interviews was to identify the optimal age group, language of instruction, appropriate level of the learning material and activities, and propose a suitable learning approach to facilitate communication and improve diabetes awareness among the target age group.

Interviews were used in this research as the data collection tool. There were different modes of communication involved in the interview such as personal interviews and telephonic interviews (39). In this research, for practical reasons, the telephonic interviews were used extensively since it was

impractical to contact participants in person. The following interviews were conducted:

Interviews with diabetes nutrition specialists

The first interviews were conducted with diabetes nutrition specialists from the Maternity and Child Health Department in the Ministry of Health in Abu Dhabi, UAE, to identify the best age to begin health education and to gain a better understanding of the appropriate nutritional needs for a given age.

The interview questions targeted areas such as health awareness, nutritional awareness, safety awareness and activities generally used to raise awareness. The questions were designed to identify the suitable target age group, the type of activities that could be used, in addition to the diabetes symptoms that the children could be taught. The interview questions were also designed to explore the way that nutritional information and guidelines are used to recommend and promote healthy food habits to children.

It was determined through these interviews that the kindergarten age was the ideal age group for our proposed system design. Research shows that children develop many food attitudes, eating habits and food preferences during preschool years (27,40,41). In addition this is also the time when young children seem to progress naturally through a developmental stage called food neophobia or fear of new foods (42). It also confirmed that early food choices are predictive of adult food preferences (43,44).

Interviews with curriculum design experts

A curriculum design expert was consulted to ensure that the proposed system followed and achieved the Abu Dhabi Educational Council (ADEC) Standards of the Ministry of Education (MoE) in UAE. The interview was conducted with the Director of Childhood Development Center in Abu Dhabi. The interview questions targeted topics such as curriculum design methods, creating engaging environments, effective curricula, program structure, administrator-teacher communication and child-development curriculum. The rationale behind the interview questions was to understand the extent to which ADEC is supporting health education and whether it is a part of the preschool curriculum. We also wanted to learn about activities that have been designed to address students' needs besides the policies and the strategies that ADEC is following to ensure an adequate level of health awareness among students.

Interviews with kindergarten teachers

Interviews were conducted with kindergarten teachers from Abu Dhabi to learn whether they teach health awareness to children and how they introduce the topic; ideally in simple and engaging way. The interview questions targeted topics related to the learning environment, teacher/child interactions, teacher support systems, engaging environments, effective curricula, language development, teacher/child interactions, awareness activities and general program structure. It also sought to identify activities that could contribute to such knowledge and if any technology was involved in these activities.

The interview was designed to collect information about the status of health education directed toward children in school. Some of the questions related to the level and scope of health awareness taught to children in kindergarten.

The questions also focused on identifying the activities that teachers follow to maintain health knowledge; whether technology could be used to support it and if any of these technologies are engaging and entertaining as a useful learning tool for children. In addition, the interview explored the level of language used to teach children about health and nutrition. The specifications collected through the interviews indicated that an E-learning system would have to address the following:

- The capability to help children develop healthy lifestyles and understand the need for and the importance of healthy food choices.
- The capability to help children learn the basic food categories and identify the different types of food that they are eating.
- The capability to provide safe playing guidelines that could help children protect themselves and others from danger by developing the correct behavior toward fire safety and traffic safety.
- The capability to identify the key diabetes symptoms that children need to be aware of.

Game-based diabetes awareness scenarios

Task requirements for our proposed prototype were presented in the form of storyboards consisting of three main categories: good nutrition guides, safe playing guides and symptoms diagnosis. In the Emirate of Abu Dhabi, English is the primary language of instruction for the target age group (kindergarten level children). The children are sufficiently fluent in English for their age, and as English was the main medium of instruction for our target age group, it was deemed appropriate that initial proof-of concept scenarios should be based in the English language. In a potential extension of this research, the native language of UAE (Arabic) would be more appropriate for older age groups when developing a similar system. The three scenarios are presented below.

Health awareness

Nutritional awareness scenario. The game concept is "Drag & Drop". This game helps develop the child's awareness and understanding of good nutrition and promotes healthy food habits by grouping healthy foods together and similarly grouping unhealthy foods together (see Figure 1). This game is simple and is designed for ease of use by 3- to 5-year olds where they simply have to drag a picture of food and drop it into the corresponding (healthy)/(unhealthy) category. For example, children drag a picture of a banana and drop it in the healthy category; or alternatively they drag a picture of candy and drop it in the unhealthy category.

Food pyramid awareness scenario. This game is "Match the Food", where children identify the food categories that will help them learn how much food their body actually needs by matching each food with its category (see Figure 2). This game is also intended to develop healthy food habits. For example, the teacher could ask the children to identify a picture of a particular food and the children could click or circle the correct picture and place it in one of several categories: poultry, fish, meat or eggs.
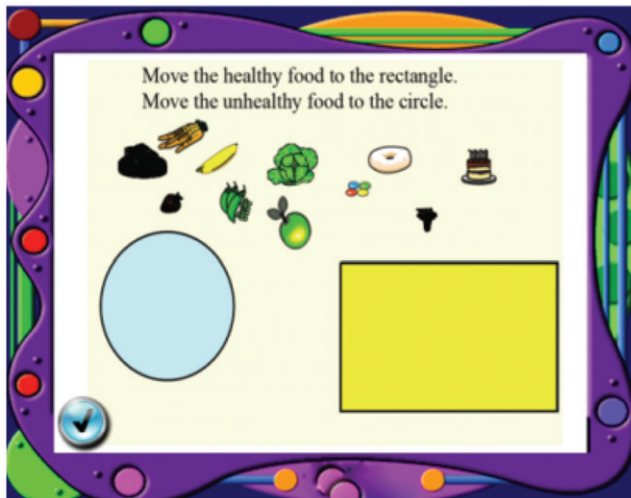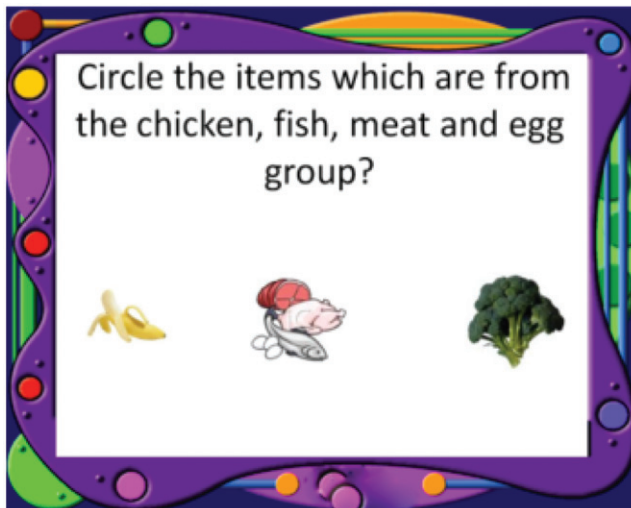
Figure 1. Nutritional awareness.

Figure 2. Food pyramid awareness scenario.

Safe play and safety

Safe play and safety awareness scenario.   In the game "What's Wrong?", the child learns the correct behavior and identifies the inappropriate behavior by selecting the correct pictures. For example, Figure 3 shows two pictures: one group of children playing in harmony and another shows two children fighting. The children are then expected to identify the inappropriate behavior by clicking on relevant the picture.

Fire safety awareness scenario.   The name of this game is "Is it Good or Bad?". Here the child is introduced to fire safety issues and understands what might cause a fire and how to avoid fire by selecting appropriate responses. For example Figure 4 shows a picture of a specific dangerous behavior: a child is

Figure 3. Playing safely awareness scenario.

Figure 4. Fire safety awareness scenario.

trying to reach a frying pan on the stove. The children are expected to identify "good" or "bad" behavior by clicking on the "happy" or "sad" smiley.

Traffic safety awareness scenario.   The name of the game is "Traffic Lights", where the child is introduced to the colors of traffic lights and must match the color of light to the correct sign by selecting the appropriate picture as shown in Figure 5.

Diabetes awareness games
Diabetes diagnosis awareness scenario.   The name of the game is "Could you be Diabetic?", where a child identifies the symptoms of diabetes in others and compares himself/herself with them by determining whether or not he/she has the same symptoms. In this game the children assess themselves,
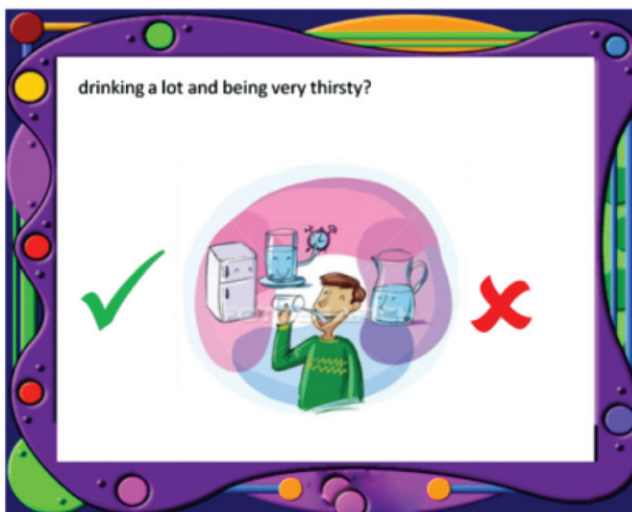
Figure 5. Traffic safety awareness scenario.

Figure 6. Diabetic diagnoses awareness scenario.

as shown in Figure 6, by identifying symptoms such as drinking excessive amount of water.

Information bank and awareness scenario.   The name of the game is "Give Me An Answer; Take a Golden Coin", where a child learns that the food he/she eats goes into the stomach and is broken down into a simple sugar called glucose which is the body's main source of energy. The glucose passes into the bloodstream where a hormone called insulin helps the body's cells use the glucose for growth and energy. If insulin is not available the cell will not receive any glucose. Children also learn that insulin is produced by the pancreas which is located behind the stomach. In a healthy body, the pancreas automatically produces only the amount of insulin needed to transport glucose
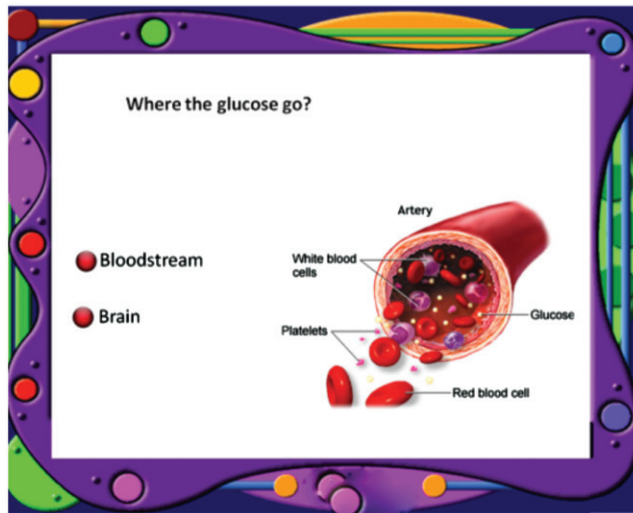
Figure 7. Bank of information awareness scenario.

from the blood into cells. For correct answers, children will receive a golden coin as shown by Figure 7.

Development of the E-learning prototype

An iterative design, implementation and evaluation process was used to develop the prototype. At each stage, there were different system features and findings, as described in the following section.

EXPERIMENTAL SCENARIO AND RESULTS

Evaluation of the prototype in this study was carried out by observing the potential users: how they interacted with the proposed prototype, handled the various tasks and their reaction towards it. They evaluated the prototype at each of the three consecutive stages.

Quality assessment

Standard software program quality assessment tools were used to assess the quality of the preliminary E-learning prototype. Due to the young age of the users, evaluation was based on observation and analysis by people who were able to make expert judgments (i.e. user's parents or guardians, kindergarten teachers and researchers. The assessment tools included observations of how the prototype was used, and evaluations of the prototype by academic staff and parents or guardians to specify the changes needed to improve the system.

Observations and interviews were the main tools used to gather data and useful information to determine the utility and appropriateness of the prototype storyboard for children aged 3–5 years (i.e. kindergarten 1 and 2) whether they were diabetic or not. The goal is to promote awareness among children whether they have the disease or not and to educate them so that they will have at least a basic understanding of the disease. This age range was chosen because it has been proven easier to change or inculcate good habits in

Table 1. Distribution of participants from Abu Dhabi in Stages 1 and 2.

Total	Gender		Age		
	Male	Female	3 years	4 years	5 years
9	4	5	3	3	3

Table 2. Distribution of participants from Abu Dhabi in the final stage.

Total	Gender		Age		
	Male	Female	3 years	4 years	5 years
50	21	29	10	20	20

children at a very young age. Further kindergarten is usually the first time children are exposed to new people, ideas and behavior.

A total of nine children from three different kindergartens in Abu Dhabi were tested at the first and second stage of prototype development. Table 1 shows the breakdown of participants according to their gender and age.

In the final stage, a total of 50 children from five different kindergartens in Abu Dhabi were tested and they were divided into two groups: female and male students. Table 2 shows the breakdown of participants according to their gender and age.

Observations

The observation method is a widely used way to collect data from an event. In this study, potential users were observed in terms of how they dealt with the system and their reaction towards it. As the study had some terminology and processes that needed to be understood by the users, they initially received a generic health awareness and related terminology lesson delivered by their teacher. In addition to that, the children were given a dedicated session that focused on terminology related to diabetes in particular, to prepare them for their participation in this study.

We used "disguised" observation, where the preschoolers were unaware they were being observed and thus behaved naturally. Disguise was achieved by letting the teacher introduce the program to the users, while the researcher stood at a distance from both and only listened and recorded the observations. The selected topics for this observation were: general health awareness, nutritional awareness, safety awareness, language interaction, teacher/child interactions, behavior, acceptance by the child, skills used, learning outcomes, social development, emotional development, physical development and intellectual development.

The observations were assigned to these four areas:

(1) *Social-emotional Development*: The teacher or instructor introduces the subject to the users and the observer evaluates the children's interest level and involvement; whether they share answers; their self-confidence and

their ability to work independently. Therefore "Social-emotional" aspects measure a child's engagement. For example, children should be prepared for the information that they are about to learn and should help each other learn. The overall score for the social-emotional development criteria was based on the aggregate score of answers to the following statements:

- Teacher or instructor introduces the subject clearly to the users.
- The user's interest does not diminish while playing.
- Students share their answers.
- Students demonstrate self-confidence and can work independently.

(1) *Physical Development* refers to if/how children develop hand-eye coordination, develop sensory awareness and interact with the system. The overall score for the physical development criterion was tabulated based on the aggregate score of answers to the following statements:

- Child is developing hand-eye coordination.
- Child is developing sensory awareness.
- Child is interacting with the system.

(1) *Intellectual Development* refers to developing a positive attitude towards learning using language to associate meaning with what is learned, developing logical thinking skills through a variety of activities such as classifying, organizing and matching information. Users listen for specific information, directions and explanations to establish whether they understood the vocabulary that was being used. The overall score for the Intellectual Development criterion was based on the aggregate score of answers to the following statements:

- Child is developing a positive attitude towards learning.
- Child is using language to bring meaning to what is learned.
- Child is developing logical thinking skills through a variety of activities such as classifying, organizing and matching.
- Child is listening for information, directions and explanations.
- Child can understand the vocabulary.
- Child understands his/her answers and responses.
- Child knows if the answer is right or wrong.

(1) *Software Usability:* These criteria relate to whether the users are interested in the system, navigate through it easily and can correct an incorrect answer and finally, clarity of the information provided to users (i.e. whether the font is suitable and readable). Here, the user's interaction with the system and the user's acceptance of the system were measured. The overall score for the Software Usability criteria was based on the aggregate score of answers to the following statements:

- Child is interested in the system.
- Child can go back and correct the incorrect answers.
- The font is convenient and easy to read.

System and software evaluation

Evaluating software for teaching and learning is a challenging task and differs from evaluating printed materials. Most of the contents of a software package is not immediately observable and only appears if the user follows particular steps. In addition, factors such as screen design, user-friendliness and the nature of the interaction must be taken into account. The purpose of this evaluation was to assess program quality and improvements, user interaction and outcomes achieved with the E-learning system. The observation evaluation method was conducted with pre-school users to assess program quality in terms of effectiveness, functionality and interface. Kindergarten teachers also evaluated the system and the evaluation criteria included the following aspects of the program: relevance to users, appropriate interaction, language level, organization of information and information quality.

The results from each assessment of the criteria provided information that was used to determine whether or not the intended outcomes were achieved and how the prototype could be improved. The assessment criteria were also designed to identify specific problems with the prototype and how they affected learning outcomes. Based on the results of the evaluation, a second and then final (third) version of the storyboards were created and evaluated in an iterative and user-informed process.
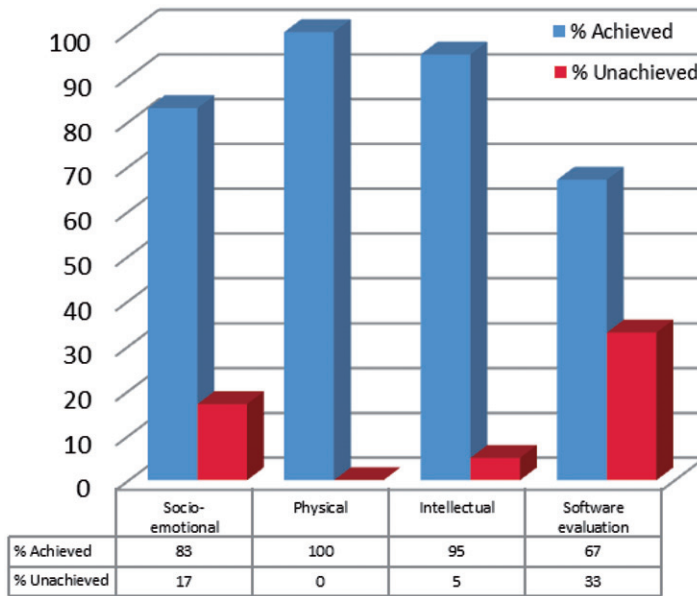
Design Stage 1 and evaluation

The first design phase was a prototype design for the game scenarios described in the Methodology section. This stage started with a small sample using nine children from three different kindergartens in Abu Dhabi, UAE (see Table 1). The evaluation of Stage 1 was conducted by using two methods: observation and software evaluation.

The evaluation of the prototype in this study was carried out by observing the potential users and how they dealt with the initial prototype and their reaction towards it. The goal of the observation was to evaluate social-emotional, physical and intellectual development and evaluate the software performance. Based on the observation, the children achieved high scores in social-emotional, physical and intellectual development. However, with respect to software performance the scores were lower; scoring 67% primarily due to the fact that the children could not go back to correct their mistakes, as shown in Figure 8.

The evaluation was completed by the kindergarten teachers, curriculum design experts and parents/guardians with the goal of improving the prototype. The evaluation criteria included the prototype's relevance to users, language level and information quality and organizational aspects of the program.

The evaluation by the kindergarten teachers, parents/guardians and nutrition specialists showed that the educational value and pedagogy of the prototype excelled in its first stage: 75% excellent, 13% good, 6% satisfactory and 6% poor performance. The perceived usefulness of computer based-learning was strongly agreed upon (100%) and considered more effective and efficient than other methods as shown in Table 3. After exploring this issue further with the users, it was acknowledged that the perceived usefulness of the system was enhanced by the audio effects and the pleasing nature of the game display.

	Socio-emotional	Physical	Intellectual	Software evaluation
% Achieved	83	100	95	67
% Unachieved	17	0	5	33

Figure 8. The satisfaction % of the software performance observation.

Table 3. Evaluation result of the teachers, parents or (guardians) and nutrition specialists.

	Excellent	Good	Satisfactory	Fair	Poor
Aspects related to educational value and pedagogy	75%	13%	6%	0%	6%
Aspects related to usefulness of computer based-learning	100%	0%	0%	0%	0%

The key features needed to improve the system based on the results of the evaluation included the need for appropriate navigation mechanisms to help children to learn from their mistakes; the addition of audio and developing a mechanism to keep a record of each child's progress by tracking his learning.

Design Stage 2 and evaluation

After considering the results from user testing on Stage 1 a number of enhancements were made to the prototype. Navigation mechanisms were added to facilitate and simplify the navigation process for the children. Sound effects were added in order to give them feedback on their work and learn from their mistakes. In Stage 2, the same users who tested the prototype in Stage 1 were used to test the second version of the system and provide feedback for the next version of prototype. This observation focused on improving the awareness of the children and not testing their knowledge. Correspondingly the preschoolers exhibited the ability to control and use the technology as confirmed by many studies (40,45). The results of the observations in Stage 2 indicated the social-emotional development increased from 80% to 90%; the physical development aspect reached 100% and the knowledge development parameter remained at 95%. Finally, the software satisfaction increased to
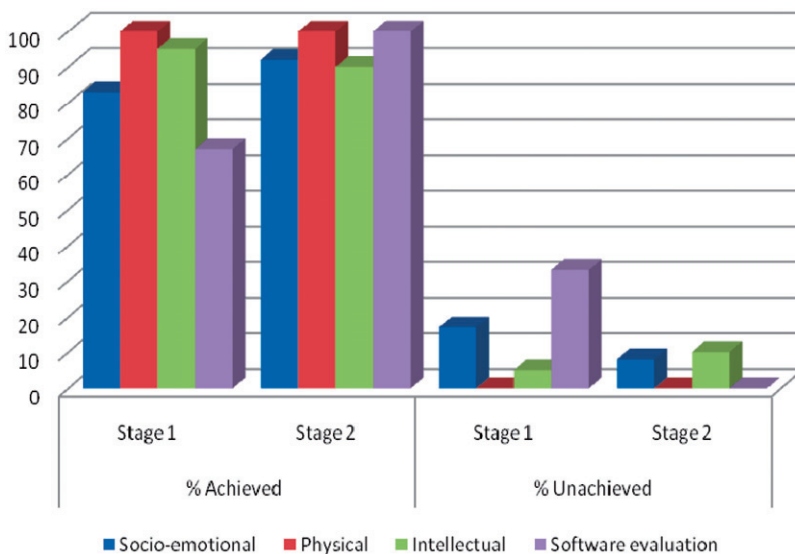
Figure 9. Satisfaction with software performance comparing Stages 1 and 2.

Table 4. Evaluation results of Stages 1 and 2 with teachers, parents, guardians and nutrition specialists.

	Excellent		Good		Satisfactory		Fair		Poor	
Prototyping stages	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Educational value and pedagogy	75%	83%	13%	10%	6%	5%	0%	2%	6%	0%

100% which was only 67% in Stage 1. This increase is thought to be due to providing the children with the ability to correct their answers. Overall, in this evaluation, the children showed a positive improvement in all the aspects, as shown in Figure 9.

The second evaluation was again directed towards the kindergarten teachers, experts and parents/guardians in order to improve the prototype. The criteria included the prototype's relevance to users, language level, organization of information and information quality. The evaluation showed that the educational value and pedagogy aspects increased significantly. The usefulness of computer based-learning was rated at 100% as it was in Stage 1. Table 4 shows the differences in the evaluations from Stage 1 to Stage 2. In particular, it shows improvement in the "Educational Value and Pedagogy" criteria from Stage 1 to Stage 2.

The findings in Stage 2 show the improvements relative to Stage 1, but there were some areas that still needed to be improved. The system monitors children with potential symptoms of diabetes and monitors the child's performance by counting the number of times each child performs the test and the resulting performance. Based on this information, the teacher is able to assess whether the child has problems understanding and can help by explaining the question and/or the process.

Figure 10. New layout of the prototype.

Design Stage 3 and evaluation

This stage incorporated Stage 1 and 2 findings and subsequent improvements to settle on a suitable platform for the final version of the prototype. Integrating a variety of tools simultaneously has been one of the biggest challenges for the E-learning prototype, as often tools that have potential uses for learning are not always easy to integrate into educational systems (28). Technical restrictions, such as firewalls, the graphics capability of available PCs and memory size, can also make ready access to new tools difficult. The "Adobe Captivate 5®" (http://www.adobe.com/products/captivate/) was the software package chosen to be used in the final version of the prototype and is considered to be an effective program for E-learning (see Figure 10). The software integrates audio and offers a customized interface for the learner to navigate and explore the simulation. In addition, the assessments and quizzes can be easily created in a professional manner using features such as bespoke buttons and enhanced backgrounds. Captivate's new Question Slide presets set up multiple choice, fill-in-the-blank and true/false quizzes. One of the other key features is the ability to design the game-based questions by adding click-boxes that must be clicked on correctly before users can progress to the next slide. The designer can also set up automatic emailing of test scores.

Adobe Captivate quiz engine maker was used to include one of the desired features: to develop and create reusable learning objects that are measurable.

The prototype exploits server-side technology, where the client's request is sent by directly to the Web server and the Web server then returns the feedback with dynamic content "pages", as illustrated in Figure 11.

The prototype has a knowledge domain which contains knowledge elements; a quiz manager that builds and manages quizzes; a user interface that is served by the session simulator, and an administration interface from which the entire system is managed.

The prototype benefited from Captivate's quiz analyzer agent, which enables educators to assess the learner's performance. The agent tracks and records the learner's interactions with the system, as well as the attempts to
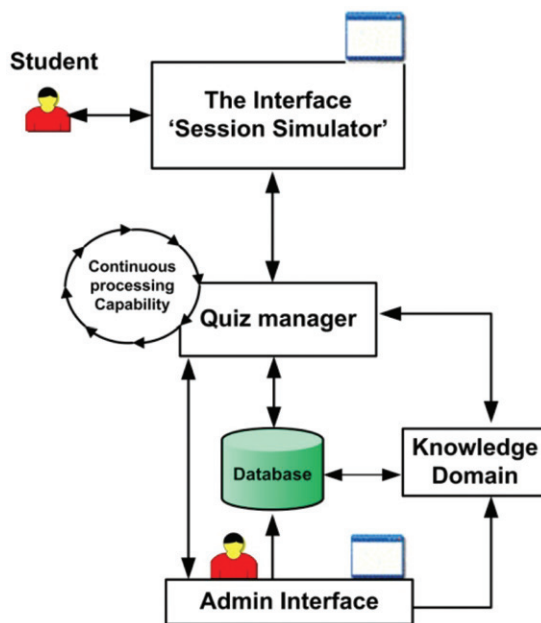
Figure 11. The system architecture.

answer the questions. The agent sends the data collected from the learning session to the database, where it can be later interrogated by the educator as shown in Figure 11.

This version of the prototype was designed so that it could track the record of each student to provide the teacher with the ability to identify issues such as any potential risks to a child's health.

Final prototype evaluation

The preschool participants who took part in the evaluation of this version of the prototype were 50 children from five different government-run kindergartens in Abu Dhabi, as shown in Table 2. The final evaluation again used the educational software observation method for preschoolers which was used in Stages 1 and 2. As shown in Table 5, the comparative results through all stages indicate that social-emotional development increased to 98% from 83% in Stage 1. The physical development aspect remained at 100% and the intellectual development aspect increased by 1–96%. After the first design stage children were allowed to change their incorrect answers in order to learn from their mistakes, as this was one of the intended pedagogical features of the system. Reflecting the iterative design approach, the system was designed so that a child's learning was measured by his/her initial attempts in answering questions, rather than subsequent corrections. This explains the lower software evaluation of 67% in Stage 1 compared to Stage 2 which incorporates the correction feature. We also needed to have a record of each subject's quiz results and the total attempts at answering questions. The number of children who had difficulties in answering questions may suggest a problem with understanding the quiz concept. Therefore, further changes were made to simplify the quiz for the children.

Table 5. The progression of satisfaction with the software performance through the three prototype stages.

Some aspects of	Stage 1	Stage 2	Stage 3
Socio-emotional development	83%	92%	98%
Development	100%	100%	100%
The knowledge development	95%	95%	96%
Software evaluation performance	67%	100%	67%

Table 6. Evaluation results at Stages 1, 2 and 3 by teachers, parents/guardians and nutritionists.

	Excellent			Good			Satisfactory			Fair			Poor		
Prototyping stages	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Educational value and pedagogy	75%	83%	97%	13%	10%	3%	6%	5%	0%	0%	2%	0%	6%	0%	0%

User-testing involved only kindergarten teachers at this stage in order to gather feedback on the final version of the prototype and to measure their satisfaction with the system. Teachers indicated that they found that tracking the record of each child to be both useful and simple. They also agreed that navigation improved so that children could take the quiz without hesitating which could cause them to lose interest.

The users' teachers and their parents/guardians were also asked to provide feedback on the final system using a questionnaire in order to inform the final phase of the system development. A group of 15 teachers participated in evaluating the final prototype using the same tool. The evaluation results showed that the educational and pedagogy value of the final prototype improved (97% scoring excellent and 3% scoring good performance), while the use of the computer as an E-learning tool remained 100% "strongly agreed" as shown in Table 6.

The findings at the final stage demonstrated the success of the prototype in delivering information on health awareness to children, and their teachers and parents. The flow in the final stage was smooth and accurate after incorporating the user-informed improvements made at Stages 1 and 2. The "Health" and "Playing & Safety" quizzes were successful and the majority of the children grasped the intended concept on the first attempt. However, a key issue that needs further consideration is connected to the diabetes awareness quizzes. When the quiz "Are You Diabetic?" was presented to children, they did not know the meaning of certain terms such as "many times". For example when asked "do you drink a lot of water?" they answered "yes" although they drink normal portions. Therefore, it was suggested that more explanations should be given to the children to understand what is meant by such questions. On the second quiz, most of the children had difficulties understanding new terms such as Glucose, Stomach, Insulin and Pancreas. The simulated demonstration of digestion turned out to be vital, as it demonstrated to them how the food we eat is

converted into glucose. This demonstration was then followed by a related quiz to assess their knowledge on that topic and it was observed that children started to build their own health awareness vocabulary and terminology to follow and incorporate what they learn into their daily routines

CONCLUSION AND RECOMMENDATION

An E-learning prototype was developed to serve as a computer-based learning method to educate children about health and raise diabetes awareness among preschool students in the UAE, where there is a growing diabetes population. The requirements for the system and accompanying guidelines were gathered from and informed by clinicians from Ministry of Health, curriculum design experts from the Abu Dhabi Educational sector and kindergarten teachers. In the literature, the use of computer-based learning is considered a successful approach. Although there are useful computer-supported educational game programs already available, they are aimed at older children, and are not suitable for the needs of pre-school children. Our proposed approach is distinct from other approaches in that it is directed at preschoolers who tend to take particular interest and pleasure in learning through game based activities. Our interface uses bright and simple pictures that support and reinforce the children's ability to identify the appropriate health-aware behaviors. The prototype system also plays music as a form of entertainment for the children and motivates them to continue with their game-based learning tasks. Another important aspect of our approach is that children who participated in the study took appropriate and focused medical terminology training sessions in preparation for experimentation with our prototype

The results of the prototype indicated that computer-based learning can generate positive learning, develop positive attitudes and perhaps behavioral changes in children. It is anticipated that children who are exposed to the proposed prototype will have an advantage versus using traditional methods, through exploiting the benefits of game based learning and user-friendly computer interface designs to learn concepts more easily and effectively. The prototype also makes learning more engaging and allows children to learn at their own pace.

The overall results demonstrate the positive impact of this technology on preschoolers. The system architecture is flexible and adaptable, which makes it suitable for various experimental healthcare studies, and is based on server-side technology, which facilitated the interactivity process. The interactivity feature allows the prototype to gather interaction data from the users, which can then be analyzed by the teacher for directed support.

Future work will focus on applying adaptive techniques to expand the system's capability to educate various age groups. One potential avenue for extending this research could include a series of controlled experiments aimed at assessing the potential of such a system to reduce the overall incidence of diabetes. Another future avenue is to make this system suitable in other social and cultural contexts.

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DECLARATION OF INTEREST

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