A Software Model Supporting Smart Learning

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1 Introduction

Smart devices have grafted themselves into our bodies and our environment at large, thus extending individual and collective capabilities [1, 2, 3, 4]. Connectivity and accessibility to resources provide users with sophisticated forms of play, communication, collaboration, and knowledge acquisition. In this context, learning in cyberspace (i.e., cyber-learning) has become a pervasive and dominant activity [5]. Cyber-learning is a critical component of cyber-cities, which provide the fundamental infrastructure for smarter cities. Cyber-learning supports constructivism by affording learners independence, exploration, self-discovery, and knowledge construction. Novel models are being proposed to support and enhance the current educational models by integrating technology, learning, and playing, resulting in what is generically termed "smart learning". Smart learning provides capabilities to support the learning process through guidance, customization, independent knowledge construction, interactivity, and accessibility [6]. Game-based learning is one example of smart learning, which integrates gameplay and explicit learning outcomes. Smart learning aims to have specific, measurable, attainable, relevant, and time-limited learning contents.

A premise motivating the design of educational games is the support of an independent learning process that is effective in easily transferring the acquired skills into the real word [7]. That is, knowledge acquisition is relevant and

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comprehensive. It covers learning contents and outcomes from various subjects, such as information technology, engineering, sciences, languages, history, and many others. Players (i.e., learners) are engaged in learning by being challenged to perform a variety of cognitive tasks, such as information collection, analysis, decision-making, reasoning, problem-solving, pattern recognition, and other physical and intellectual activities. As a simple example, learning the alphabet by children involves interacting explicitly with shapes, sounds, and images, and implicitly with meanings, relationships, and composition. Learners engage in the knowledge acquisition process through pattern recognition, meaning formation, concept association, and concept composition. These basic cognitive tasks, coupled with independent progress, constitute one aspect of what we define as *smart learning*.

Even though traditional education and GBL share learning as their main goal, GBL is a radical departure from tradition. As such, it presents researchers with the grand challenge of how to design a computational model of the learning process that captures effectively the cognitive tasks identified by cognitive scientists. In the traditional education context, teachers, mentors, peers, and students act together as facilitators of learning, while GBL seeks the introduction of an unknown context based mostly on assumptions from traditional education. Thus, another major challenge is to disentangle GBL from these assumptions.

Nevertheless, despite these challenges, researchers have been proposing frameworks designed to support the game based learning process [8]. However, software models based on these frameworks, which would form the basis for designing educational games have not been adequately addressed. Indeed, new software object oriented models are needed to facilitate the implementation of games that support GBL. Also, completely new models of the learning process are needed to integrate technologies and learning sciences [9, 10].

The rest of the paper is structured as follows: Sect. 2 presents a literature review of previous works related to GBL framework design. In Sect. 3, we elaborate a game-based learning software model and describe its architecture. Section 4 describes the implementation of our proposed software model. Section 5 presents the results of our experimental evaluation. Section 6 summarizes the tasks we have completed in this research.

2 Literature Review

There is a wide agreement among researchers that games can effectively improve education and can be helpful and useful for teaching complex concepts and skills [11]. Several comprehensive meta-analyses demonstrate the positive impact of GBL on learning [12, 13, 14, 15]. A study found out that 70% of high school students left school because they were not interested or motivated to continue their education [11]. Moreover, a pan-European study surveyed 500 teachers showed that motivation was increased when computer games were included into the educational process [11]. The work in [16] posits that students are motivated through: competition and goals, as players feel personal attachment to a goal, rules, choice, fantasy, and challenges [17]. Yet, others see that GBL research has been based on claims that cannot be substantiated [12]. The disagreement stems from the lack of balanced integration of concepts from pedagogy, instruction, technology, and content into an operational software model. Without this balance, GBL development becomes ad hoc, and the resulting product will not meet the expectations of game makers, students and educators [12].

Proposed frameworks to guide GBL development deal with design at highly abstract conceptual level. In general, these frameworks are far removed from software design. An early model was elaborated by Kiili in [18]. Kiili's Experiential Gaming Model tries to integrate game design, flow theory, and experiential learning theory. Game challenges should commensurate with the player's skill levels to keep the player engaged with learning activities [18]. Another model is the Game Object Model (GOM) [19], which is a naïve attempt at developing an object-oriented model of GBL. The decomposition of the model into pseudo objects and the use of notation and terminology inconsistent with object-oriented design highlight the wide gap between GBL researchers from the educational side and GBL software developers. By its reliance on highly abstract cognitive tasks, the GOM proposal fails to address modeling issues. A recent proposal is the synthesis of a GBL framework developed in [7, 8]. This framework identifies learning, instruction, and assessment as the three major dimensions of GBL all linked with game elements [8]. Each dimension contains the relevant components that contribute to learning, instruction, or assessment. Specifically, the dimensions are:

1. Learning consisting of learning objectives, goals, and learning content.
2. Instruction consisting of games elements (context, pedagogy, learner specifics, and representation) and instructional design.
3. Assessment consisting of feedback and debriefing.

In order to have an effective educational design of games, the alignment between learning, instruction and assessment aspects should be achieved. The learning objectives, the player goals and the learning content are defined in the learning column. The game learning cycle imbedded in the instruction column consists of user feedback, user behavior, user engagement and user learning. While designing the instructional design, designers must take into consideration that the player actions must be followed by sufficient feedback in order to engage the player in the game for better effective learning. Finally, the assessment column contains two elements which are: debriefing element by which the player makes a connection between the experience gained by playing the game and the real life experience, and the system feedback element which represents displaying the score to the player.

This framework can be used as a design aid that can guide new GBL design and improve existing game designs by identifying their structures and components and refining them to meet the requirements. Moreover, this framework can be used as an evaluation tool as one of its elements is the assessment concept, which helps in evaluating the player after playing the game [8].

3 Proposed Software Model

None of the proposed frameworks addresses GBL from a software design perspective. These frameworks are described in highly conceptual terms that do not provide any guidance for software design and implementation. For example, the concept of learning remains undefined, and even though we have an intuitive idea about it, we still need an operational definition to guide its software implementation. Hence, we elaborate an analysis and refinement of the framework in [8] in order to derive an object oriented software model, which is then used as the basis for the implementation, thus bridging the gap between informal design and implementation. Thus, our main concern is to refine the framework by expressing it as a software design so that implementability issues can be directly addressed. As an example, Fig. 5 illustrates how we decompose the concept of learning into concrete tasks. Our resulting design will lend itself easily to implementation using any object-oriented approach. The proposed software model consists of four perspectives: system architecture, model-view-controller architecture, structural design (class diagram), and the behavioral design (state chart). We present each one of them in the following sections.

3.1 Three Tier Architecture

We mapped the game-based learning framework into a three-tier system architecture (See Fig. 1) which consists of: (1) the presentation layer that represents the user interface to translate the tasks and the results to visual objects the user can understand; (2) the business logic layer that executes commands and calculations, and makes logical evaluations; and (3) the data layer where the information is stored and retrieved from a data model repository.

When the learner plays an educational game, he/she interacts with the concepts and the objects of the game. Selecting the right concept and associating them with the objects reflects the learning goal and the user behavior and helps the player to gain decision making skills.

One way to support user engagement is interactivity. There are three forms of interactivity: the first is the physical interactivity which represents the player's behavior while interacting with the game. The second is the visual interactivity which reflects the player responses to the visual objects of the game. And the third is the sound interactivity which is represented by the player's reactions to sound triggered by game objects, and the system feedback provided by the game (Fig. 2).

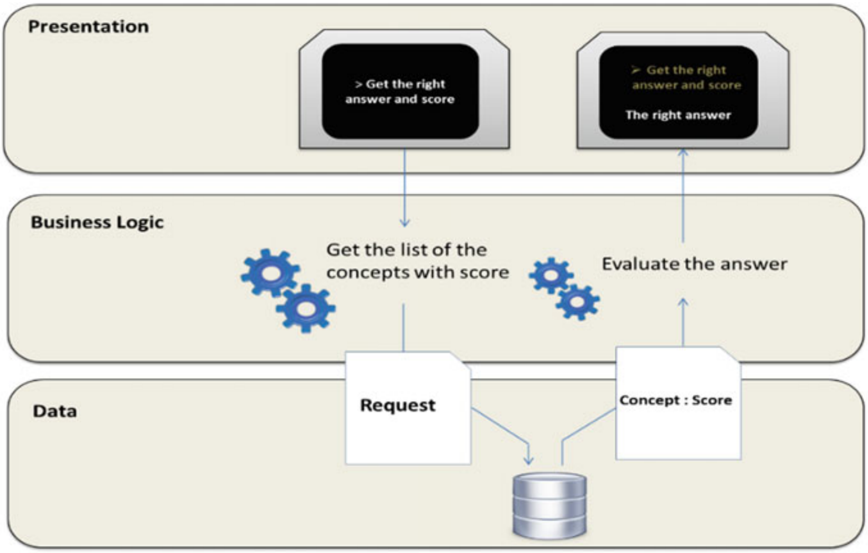
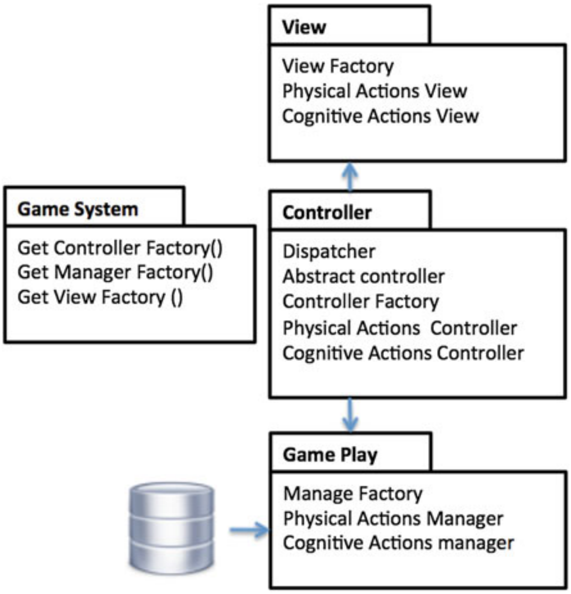


Fig. 1 System architecture

Fig. 2 MVC architecture



3.2 MVC Architecture

In addition, we mapped the three-tier architecture into a model-view-controller architecture, which shows the packages and their classes that are used to implement an educational game (see Fig. 2). All the mutable data, the positions, the units and the status of the objects are included in the game system that checks and changes the states of the game. Once the player interacts with the game, the controller package handles the input provided by the player and it communicates with the game play layer to handle the data of the requests.

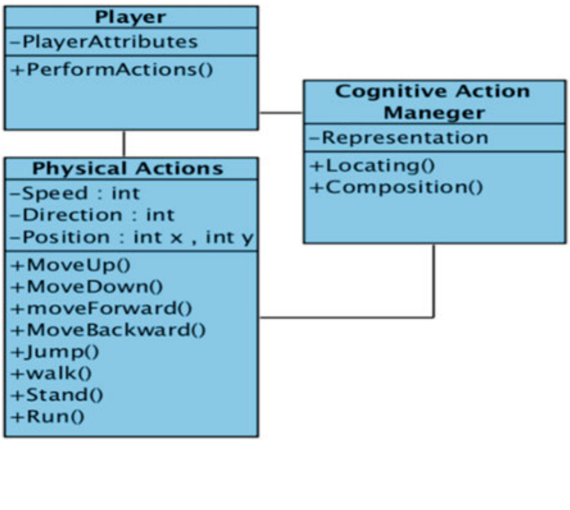
Once the game play layer processes the request, it retrieves the needed information from the data model repository based on the input provided by the player, and then returns it back to the controller which communicates with the view layer to decide what to display for the player.

3.3 Class Diagrams

For the refinement of the MVC architecture we developed a class diagram. For example one interesting class diagram is shown in Fig. 3. This class diagram models the player, which consists of three classes, one representing the player and the other two representing the cognitive and physical actions that the player is capable of performing. The player class consists of the activities that he/she can perform while playing, and descriptive attributes. Examples of descriptive attributes of the player may consist of: memory, acquired knowledge, position, sprite, speed and direction.

The physical actions class represents the physical actions available to the player which are carried out by the avatar that' is under the control of the player. The

Fig. 3 Player class diagram



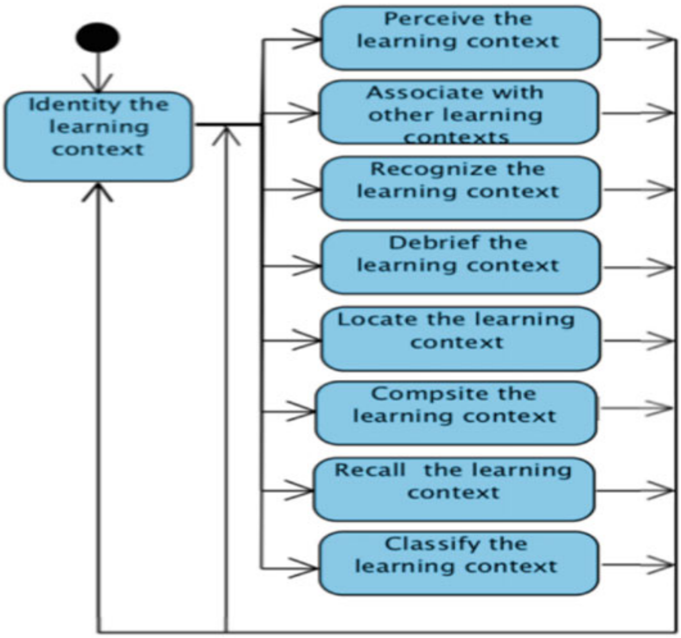


Fig. 4 Player state chart

cognitive actions contribute to knowledge acquisition (i.e., learning) through concept formation elaborated from basic building blocks. These blocks are individual atomic concepts that can be composed to form more complex blocks, which, in turn, can themselves be used for further composition, thus, increasing the complexity of the knowledge being acquired.

3.4 State Chart

For the player to learn while playing an educational game, he must perform cognitive activities by interacting with objects in the game in order to acquire knowledge. The following state chart (Fig. 4) illustrates the states of one object of the game, which is the player. For an object to move from one state to another it must carry out relevant actions during the interaction with the other objects, thus resulting in a state change. Basic cognitive actions that are provided consists of: perception, association, recognition, debriefing, locating, composition, recalling, and classification. Physical actions are the basic movements, such as: select, jump, walk, run, and many others.

4 Game Implementation

As an illustration, we consider the implementation of the main class "player" using the game maker engine [20]. This process requires: (1) structuring the knowledge to support gradual acquisition; (2) building an interaction matrix; and (3) elaborating the main object "player".

4.1 Knowledge Structuring

The literature on games for learning argues that the multiplicity of exploration paths gives players (learners) opportunities to tailor their learning experiences. However, there is a no link between these paths and explicit learning content structuring to guide the learner in the construction of learning paths by "freely" navigating the underlying structure. Hence, structuring the learning content as a concept map captures independent and gradual exploration, whereby links define paths and concept ordering defines levels of progressive evolution from basic to advanced concepts. Viewed as small-scale ontologies, concept maps help learners organize their knowledge and their thinking, and stimulate their cognitive skills. Even though the underlying representation is highly structured, the learner's exploratory activities are spontaneous and guided by his/her actions and decisions. Figure 5 shows a concept map that structures the learning content of Arabic for KG students.

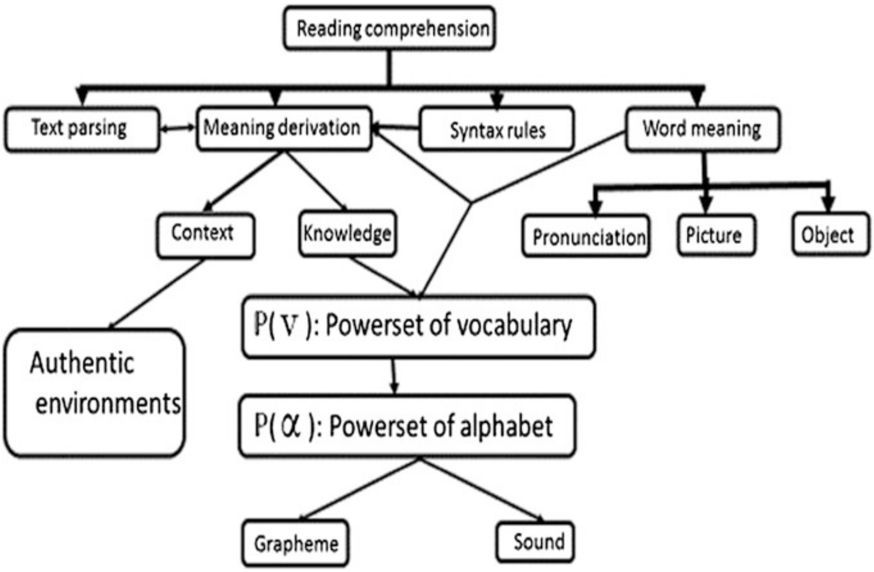


Fig. 5 Knowledge structuring using a concept map

4.2 Interaction Matrix

The interaction matrix captures all the interactions among objects within the game world. Our player interacts with objects through physical and cognitive actions, as mentioned earlier. Table 1 provides a generic summary of the interactions between the player and the various objects.

Note that the set ca belongs to ‖ (Cognitive Actions) (i.e., *ca* ⊙ ‖ (Cognitive Actions)), the set *pa* belongs to ‖ (Physical Actions) (i.e., *pa* ⊙ ‖ (Physical Actions)), and the objects O_i and O_j are members of the set {O: O is an object in the game world), where ‖ is the power set construct. The value in a given matrix cell indicates the nature of the interactions. In Table 1, X stands for no interaction, *ca* stands for a set of cognitive interactions, and *pa* stands for a set of physical interactions. Instantiating O_i, O_j, *ca*, and *pa* in the table will result in a complete description of all the possible interactions among the objects and the player.

We need to associate meanings with the actions involving the player and the generic objects. For example: what is the meaning of the cognitive action "perceive"? Through playing, the player acquires knowledge about the instantiated objects in terms of the cognitive actions. As for the meaning of "perceive" as a cognitive action, we define it as "the ability to see and recognize an object". Hence, perceiving the object means, the ability to see the object and knowing everything related to it. In object-oriented terms, given that any object is endowed with attributes and services to reveal itself, this ability amounts for the player having full access to the object of interest. The information that the player perceives about a given object are the characteristics and the effects of methods of that object. For example, Fig. 6 depicts a simple object "SPARROW", which, when discovered by the player, will expose knowledge about itself, and even sing. Table 2 summarizes some of the cognitive activities of the player and the type of questions he may be able to answer once having acquired new knowledge.

Agent technology was used to implement the game architecture we defined in the previous section by having two agents, the first one is to represent the player and the second one is the assistant agent to help in game calculations, evaluations and management. The actual game introduces alphabets and a picture as objects, and the player must construct the right word that is related to the picture using the displayed alphabets. In this way the game supports two of the knowledge acquisition activities: identification by which the player identifies the context and association by which the player relates the context to the right object.

Table 1 Generic interaction matrix

	Player	O_i	O_j
Player	X	*ca*	*pa*
O_i	*ca*	X	X
O_j	*pa*	X	X

SPARROW
Color Song Name
What-is-your-name() What-is-your-color() Sing-for-me()

Fig. 6 Object instance

Table 2 Cognitive activities meanings and questions

Cognitive activity	Definition (www.dictionary.com)	Example of questions
Identify	To recognize or establish as being a particular person or thing	What do you see?
Perceive	To recognize, discern, envision, or understand	What is color of the object?
Associate	To connect or bring into relation, as thought, feeling, memory and many other	What category does this objet belong to?
Recognize	To identify as something or someone previously seen, known and many other	Which object is the smallest?
Locate	To assign or ascribe a particular location to (something)	Where can you put this object?

5 Experimental Evaluation

We conducted an experiment at a local primary school to assess the effect of our approach. The experiment was held in the morning and consisted of a one hour familiarization with the system session and two 45-min sessions, one for females and one for males. Participants were first grade divided into two groups consisting of 30 female student and 28 male students.

In the first hour of the experiment, the application was saved into the school's laptops. Moreover, the teachers arranged the tables and chairs and provided the students with headphones to give the chance for every student to play alone without interruption. In the experimental session, students were asked to open the application and start playing the game. They were informed that they will not receive any support from any one, including the teachers. The performance of each student was recorded via Steps Recorder. Once finished, the teachers collected their responses files. After files where collected the results were recorded based on the student's choice in the test part.

The results in Table 3 show the percentage of students who were able to recognize the different shape of a given letter. The leftmost instance of the letter is the

Table 3 Shape recognition results

Shape	ق	ـق	ـقـ	قـ
% Value	1	0.97	0.864	0.864

canonical shape that is introduced for learning the letter. Thus, all students were able to recognize it. The others shape were not introduced and the students were asked to identify them. The middle column presents a letter that is close to the original, thus the students did not have difficulties recognizing it. In the last two columns, even though the shapes presented a bigger challenge, 86% of the students were able to recognize them. We consider this process as a learning transfer activity, implying that the students are capable of using previous acquired knowledge in new learning situations. We attribute this gain to the multi-modality that GBL provides.

6 Conclusion

Current research confirms that game-based learning has potential benefits in the educational context. Being a novel approach, GBL presents several challenges, among them how to design a software model of GBL that is implementable. Our work addressed this challenge directly and provided a complete solution, demonstrating that given an abstract framework, we can capture it in software design and implementation. Our software model consists of a system architecture, a model-view-controller architecture, a structural design, and a behavioral design. Our implementation of the model uses agent technology, wherein agents represents smart object of the GBL world. In this context, agents model very nicely the behavior of learners, tutors, and other components in the GBL world. This technology supports the intelligent interactions between the player, non-player characters, and other game components, naturally lending itself to modeling of educational games. Hence, agent technology was used to derive our design and implementation of an educational game from the framework.

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