# Pedagogy Elements, Components and Structures for Serious Games Authoring Environments

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## ABSTRACT
'Serious games' exploit gaming technologies in creating a fun and interactive virtual learning environment that promotes experiential learning. Many researchers believe that such innovation in learning technology can better motivate present day entertainment-driven learners to experience learning through meaningful learning activities as opposed to traditional learning approaches. In this paper we describe the elements, components and structures of pedagogy in serious game for use in a serious game authoring environment.

## Categories and Subject Descriptors
K.8.0 [**Personal Computing**]: General - *Games*

## General Terms
Design, Theory.

## Keywords
Serious games, digital game-based learning, serious games authoring environment.

## 1. INTRODUCTION
The idea of exploiting gaming experience and technologies in construction of a fun and interactive learning environment is an innovative approach in promoting experiential learning. In fact, the use of digital games (referred to as video or computer games) in the context of education, training and pedagogy can be traced back to the 1980's [1-3]. However, such intention was greatly affected by the negative views on the effects of digital games as described in [4-6]. Despite this, there is a growing number of integrated views realising the potential of digital games in learning.

The 'Serious Games Initiative' initiated by the industry focuses on the uses of digital games in education, training, health and public policy presents an overview of industrial efforts aligned to academic research efforts that supports such views [49, 50]. The term 'serious game' is widely used nowadays to represent digital games developed for non-entertainment purposes [51 - 53]. While most of the e-learning technologies lack in engaging learners of all ages in learning, we firmly believe that serious games can provide fun, engaging and interactive learning content that appeals to present day entertainment-influenced learners. In fact, recent perceptions of e-learning have been realigned from electronic-learning to 'effective-learning' to promote meaningful learning activities through the use of technological elements which suit learners' lifestyle [52].

The change in world trends and emergent cultures such as information technology and gaming has changed the lifestyle of many. Such change has greatly affected the mindset and motivation of the younger generation on the importance of education described by Prensky as the "Engage me or enrage me" group which represents most of today's learners [7]. Nowadays, universities and colleges worldwide are experiencing decline in applications from students into science courses despite the growing needs for scientists and engineers in industry [8-11]. Findings reveal that such decline is, in part, related to the interest, motivation and perception young learners have toward science and technology [8, 12]. Although educational content and curriculum are responsible for raising and maintaining the interest of young learners in the area of STEM (Science, Technology, Engineering and Mathematics) subjects [8], education is a complex process that involves humans. There are many variables that determine the outcome of the process and many variables are controlled by learners themselves. It is certain that the change mentioned has affected variables such as learners' behaviour, needs and lifestyle. Pedagogical approaches toward educating this generation of learners presents a huge gap for effective learning to take place. Education is now in dire need for any solutions that would work with the new generation of learners.

In the recent years, the application of gaming technologies in education has gained tremendous interest from different sectors including government, academia and industry [13-15]. Many agree that it is now appropriate to take advantage of gaming technologies to create a new generation of educational technology tools to equip learners of all ages with necessary skills through experiential learning [15]. As positive impressions on digital games continue to spread, various programmes of research have been conducted to realise the use of game content at various levels of learning. In general, this research can be categorised into feasibility studies of game-based learning where most are pilot projects which use commercial digital games or specifically designed digital games content for learning purposes to study the impacts of such applications [9-23], serious games design models and guidelines which aims to integrate various pedagogical approaches into game design to formulate a framework for designing serious games [25-32], and alternative learning opportunities using games as a tool [33]. A recent Federation of American Scientist's (FAS) Summit on Educational Games that identified possible areas of research that focus on the *design of games for learning* and *adaptation of simulation to learning environments* [15, 34] is inline with our own research activities on games for learning.

Our primary focus in this paper is to define the pedagogical elements, components and structures that can be composed

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using components in digital games to create serious games that can be used for learning and teaching purposes. These pedagogical elements, components and structures can then be used in a software environment similar to a game editor application that ships with commercial games that allows enthusiast game-players to create customised items, characters, enemies, models, modes, textures, levels, story lines and game modes to author serious games. In Section 2, we describe the components of serious games and the pedagogies we can expect from serious games to define pedagogy elements in serious games. We then describe how these pedagogy elements are used to form pedagogy components for serious games in Section 3 and structure the pedagogy components to cater for different usage in Section 4. In Section 5 we emphasise the need for authoring software for domain experts who wish to adopt digital game-based learning and how the pedagogy elements, components and structures defined in this paper can be used in such an authoring environment. In Section 6 we present our conclusions and our future work.

# 2. ELEMENTS OF PEDAGOGY IN SERIOUS GAMES

## 2.1 Components of Serious Games

Most serious games are designed to replicate the learning experience of Common Off-The-Shelf (COTS) games through the effective use of multimedia elements such as text, graphic, audio, animation and video that are organised and programmed to response to learners' actions. Individually these media elements communicate information to learners and have been used to define various learning systems generally known as *Edutainment*.

In the context of digital games, these elements have been used effectively to compose screens, cut-scenes, game tutorials and game levels that are organised artistically and strategically to elicit optimal entertainment experience through play. These sections can be distinctively represented by a collection of responsive and non-responsive components that are organised for a specific purpose are categorised as *user interfaces* and *in-game components*.

- ***User interfaces*** are used to present visual information such as instruction and statistics that are represented visually using text or a set of 2D graphics. These components can either be a standalone component or linked to a collection of in-game components that can affect the statistics in the serious game. These user interface components are organised on a panel that occupy an absolute space on the screen or appears dynamically on screen for example in Heads Up Displays (or HUDs) overlaid onto the game screen.
- ***In-game components*** represent actors and objects that are used to stage happenings in a virtual space. Actors and objects are represented in 3D graphics and audio to present its distinctive identity. These components can also possess behaviours that are represented mathematically to respond "physically" and even act "intelligently" in the virtual environment according the degree of realism desired.

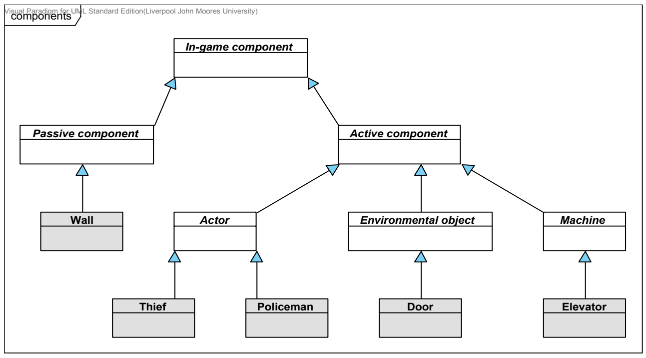


Figure 1: Class diagram for in-game components (showing example instances in shaded boxes). This is not meant to be an exhaustive list but rather an example of the abstract hierarchy that can be expanded in the future.

## 2.2 Pedagogies in Serious Game

Digital games have been applying theories from disciplines such as psychology as simple 'recipes' to engage game-players by allowing them to learn as they play [32-33]. Shaping the learner's behaviour by encoding knowledge of cause and effect with a behaviourism approach and constructing knowledge through active participation with the environment based on constructivist view have been the core pedagogy in describing the success of well-designed digital games. These pedagogies can be used creatively to steer human curiosity and engage them deeper into the game-play. Effective application of these pedagogies invites game-players to continue challenging themselves and thus promotes repeated play. Likewise serious games can be designed using these pedagogies to arouse learners' interest on a subject and transform these learners to active learners that constantly update themselves on the subject matter.

## 2.3 Pedagogy elements in Serious Games

The components described in Section 2.1 are useful in creating pedagogy elements in serious games as learning objects and to support learning. Based on the pedagogies described in Section 2.2, we derive three elements of pedagogy using components of serious games described in Section 2.1 by inviting learners to study (1) the properties and behaviour of in-game components, (2) the relationship between in-game components and (3) the solving of problems in the scenario defined. We shall describe the three pedagogy elements and map each element to Bloom's 'Taxonomy of Educational Objectives' to aid domain experts in defining assessable learning objectives in serious games.

### *2.3.1 Properties and behaviours of in-game components*

Actors and objects represented in serious games are valid subjects for learning. Learners can learn by simply observing the properties of these in-game components that are presented visually and aurally. Learners can also interact with these in-game components to learn on the "physical" and "cognitive" behaviour possessed by these in game components. The amount of knowledge extracted from these in-game components depends on detailing of the actors and objects' identity. Some classes of actors are programmed with the ability to converse with other actors through dialogue. The contents in dialogue can be presented aurally or visually by using user interface components (or both). Dialogue is best used as pedagogy to direct or guide learners in serious games. Learning about the properties and behaviour of actors and objects allows learners to develop an understanding toward these in-game components and relationships between properties and behaviours encoded. Properties and behaviour of in-game components are pedagogy elements that can be assessed as the knowledge domain in Bloom's Taxonomy.

#### *2.3.2 Relationship between in-game components*

Learning about the properties and behaviours of actors and objects allows learners to classify these in-games components into its distinctive classes and subsequently develop knowledge of understanding on the relationships that are defined among actors and objects. These relationships are meanings designed within the interactions between the in-game components and can be learnt by observing the cause and effect of an interaction. Every action taken by the learner is associated with a meaningful response which can be represented visually or aurally (or both) to foster construction of knowledge. Interacting with in-game components can help learners to develop knowledge and promote understanding on the usage of these in-game components in solving problems. The relationship between in-game components can also help learners to develop greater understanding toward actors and objects observable via emergent properties that are introduced through interactions. Emergent properties are noticeable once learners have developed an understanding of the relationships and applications of the collection of parts as one. Meanings defined through the relationships in serious games are assessable as comprehension in the cognitive domain under Bloom's Taxonomy.

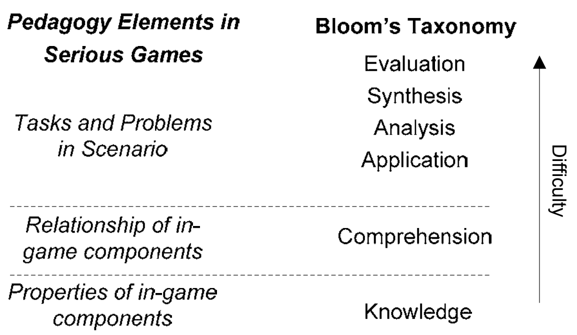


Figure 2: Pedagogy Elements in Serious Games on Bloom's Taxonomy.

#### *2.3.3 Tasks and problems in a given scenario*

Performing tasks and solving problems interactively in a scenario staged by domain experts provides learners with cognitive challenges of higher level in Bloom's Taxonomy. Tasks are direct interactions with in-games components that serve a specific purpose. Performing a task in serious games requires learners to have knowledge properties and behaviour of the in-game components involved and the relationships that exist between these components with learners. Defining and arranging a set of tasks to cognitively challenge learners is the essence of designing problems in serious games. These problems can be designed to reflect educational objectives that require learners to perform analysis, application, synthesis or evaluation in order to complete the tasks assigned. The task itself can also exist as a problem in a defined scenario. Tasks are measurable interactions and therefore problems presented to learners are assessable. Performing tasks and solving problems are learning activities that help in building learners experience and cognitive skills in approaching problems. An example of a real-world task might be demonstration of knowledge of safe handling of a certain chemical or operating a machine correctly.

## 3. COMPONENTS OF PEDAGOGY IN SERIOUS GAMES

In serious games, components of pedagogy are *game screens*, *cut-scenes*, *game tutorials* and *game levels* that can be used for designing varying learning structures. These pedagogy components can be used as separate or integrated instructional tool(s) for the nine sequenced learning events defined by Gagné [46-48] as conditions for learning. Gagné's 'Conditions of Learning theory' proposes nine instructional events and corresponding cognitive processes: gaining attention (reception); informing learners of the objective (expectancy); stimulate recall of prior learning (retrieval); presenting the stimulus (selective perception); providing learning guidance (semantic encoding); eliciting performance (responding); providing feedback (reinforcement); assessing performance (retrieval); and enhancing retention and transfer (generalization) to facilitate learning at various levels [32-33]. The remainder of this section describes these components of pedagogy in serious games in relation to Gagné's theory.

### 3.1 Game screens

Game screens have many instructional uses: to display menus to access other features in the game software, for displaying game objectives and to display game statistics. Generally game screens are useful for displaying static information using textual and graphical elements with minimal interactive elements to complement digital games as standalone software. Pedagogically it is ideal for informing learners on the learning objectives of the immediate play segment in a serious game. Game screens can also be used alternatively for stimulating recall of prior learning but are less effective compared to cut-scenes described below.

### 3.2 Cut-scenes

Cut-scenes are animated movies that exist in between sections of the play segments and use storytelling to immerse game-players and promote continuation in digital games. It can be created as pre-rendered or scripted real-time animation to present information visually. Cut-scenes in general are computer generated animations that are widely used in delivery of lesson to aid learners in visualization of concepts in topics such as sciences which are difficult to describe or demonstrate physically known as multimedia learning. In serious games, cut-scenes are best used for gaining learners' attention, informing learners of the objectives, stimulating recall of prior learning and presenting the stimulus. As a passive approach, cut-scenes can also be used in providing guidance in learning.

### 3.3 Game tutorials

Game tutorials in digital games guide learners to control an avatar (actor) and interact with actors and objects in the virtual space. Although it is guided, learners are given the freedom to interact with the virtual environment. Often games tutorials include a character of the mentor archetype that provides guidance to game-players in completing the assigned tasks in the tutorial. Game tutorials are not mandatory in most digital games but undergoing the tutorials can certainly improve a game-player's performance and experience during game play. Because feedback in a game is embedded within the interactions through the cause and effect relationships defined, learners are notified of errors almost instantly and thus facilitating knowledge construction. Serious games can also adopt such an approach in tutorials. In the context of Gagné's conditions of learning, game tutorials are best used as an interactive approach in providing the stimulus, providing learners guidance, eliciting performance and giving feedback.

Table 1: Components of pedagogy in relation to Gagné's Nine Instructional Events.

| **Gagné's Nine Instructional Events** | **Game Screen** | **Cut-Scene** | **Game Tutorial** | **Game Level** |
|---|---|---|---|---|
| Gaining Attention | | **H** | | |
| Informing Learners of the Objectives | **H** | **M** | | |
| Stimulating Recall of Prior Learning | **M** | **H** | **L** | **L** |
| Presenting the Stimulus | | **H** | **M** | **L** |
| Providing Learner Guidance | | **M** | **H** | |
| Eliciting Performance | | | **H** | **H** |
| Giving Feedback | **M** | | **H** | **H** |
| Assessing Performance | | | **L** | **H** |
| Enhancing Retention and Transfer | | | | **H** |

**PRIORITY**

**H** = High, **M** = Medium, **L** = Low

## 3.4 Game levels

Game levels are play-segments organised to challenge game-players in an incremental difficulty fashion. It is best used in serious games for constructing scenarios that reflect happening in reality which involves actors and objects in a virtual space. Game levels grant learners the freedom to experiment with possible solutions to the problems presented in the virtual environment and therefore expand their knowledge as in experience through problem solving. Tasks and problems presented in game levels are often more challenging and complex with less guidance compared to game tutorial. In view of Gagné's instructional events game levels are ideal for giving feedback, assessing learners' performance and enhancing retention and transfer of knowledge.

# 4. STRUCTURES OF PEDAGOGY FOR SERIOUS GAME

## 4.1 Serious Games usage modes

Pedagogically, serious games are only an illustration of concepts designed as interactive software with rules and objectives by domain experts [35]. Ultimately, serious games can be used in two distinct modes; *interactive mode* and *machinima mode* as active and passive approaches to promote learning.

- ***Interactive mode*** takes full advantage of games technology to provide an experiential learning environment for learners to test their knowledge into a simulated environment. The interactive mode requires active participation from learners to provide inputs to the virtual environment. Feedback from the interactions are direct experiences that allow learners to establish relationships among concepts, skill elements, objects and experiences to cognitively derive meaning from these relationships. The interactive mode can also be extended to support multiple users for scenarios which require team efforts in solving problems.
- ***Machinima mode*** is a non-interactive, real-time visualization of a scenario designed by domain experts for demonstration purposes which can be used in presentation sessions. Such illustrative content either be a scripted animation of a scenario or recording of learner's activity during serious play. The machinima mode offers pedagogue-centred features in the model that complements presentation of learning material in a formal classroom setting. It can be used to help learners visualise concepts presented by domain experts. In addition it can be used as a mechanism for reflection and performance feedback by domain experts.

## 4.2 Pedagogy structures for Serious Games

These usage modes identified in section 4.1 are influencing factors on the pedagogy structures for serious games. Based on these factors we propose four pedagogy structures that comprise the components defined in Section 3 for creating teaching tools and learning materials that complement traditional pedagogies. We present a 'complete game structure' model and three sub-sets: 'presentation-based structure', 'training-based structure' and 'scenario-based structure' that are designed to serve specific instructional events. Learning content based on these structures are smaller in scale and meant to be used as light-weight software applications similar to the concepts of mini-games. In the following sections we describe these pedagogy structures and present serious games examples that use them.

### *4.2.1 Complete game structure*

Complete game structure embeds all cut-scenes, game screens, game tutorials and game levels into a single software application that is distributable as courseware for self-learning purposes. This structure is best used as supplementary learning material that allows learners to learn interactively at their own pace. Game screens and cut-scenes are use to complement game tutorials and game levels in creating more manageable segments (or lessons) to address different learning outcomes. These lessons may or may not consist of all nine instructional events identified by Gagne individually but exist as a whole within the serious game.

The complete game structure is usually driven by storytelling that reflects the knowledge domain and situated in a simulation of a series of "real" scenario with predefined set of interactions that can be measured against the learning objectives and to reflect learner's performance. A learner participates in the virtual environment taking the role of an actor or object defined in the story or as a spectator. The learner views the virtual world in some perspective (e.g. first or third person) depending on the interaction model which has the best pedagogical impact to the users. The complete game structure can be a series of interactive tutorial knowledge and skill training sessions or be designed as a complete version of serious game which progressively flows from an animated introduction to a series of tutorial and subsequently to various scenarios with different learning outcomes and increasing level of difficulty, similar to our description of an educational game model in [32-33]. Figure 3 represents the complete game structure which can be further organised into a list of game tutorials and game levels accessible via game screen which act as menu.

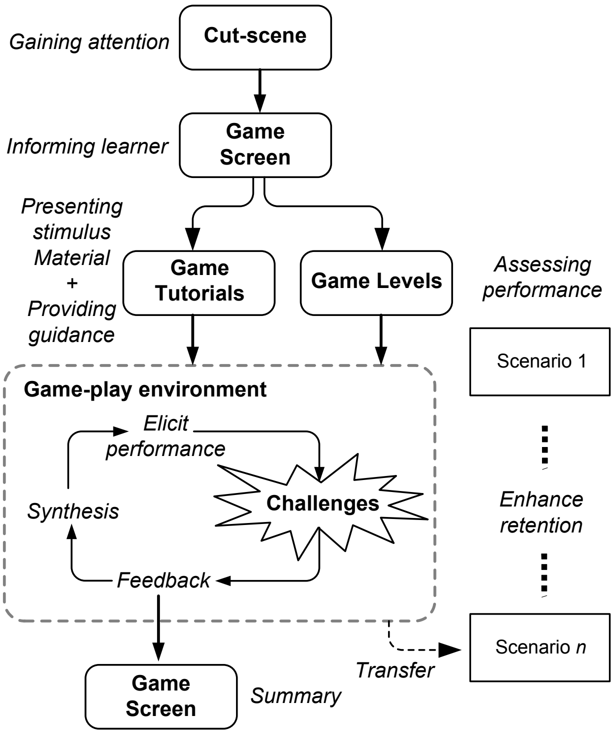


Figure 3: Complete game structure as pedagogy structure for serious games.

*America's Army* is an example of a serious game that employs such a structure. *America's Army* is a tactical squad-based first person shooter developed and published by the US Army primarily as a recruitment tool that reflects a true representation and expectation of the US Army [36-37]. The single-user mode serves as mandatory training sessions for learners to obtain skills and knowledge before engaging in the battle in multi-user mode.

### 4.2.2 *Presentation-based Structure*

Presentation-based structure is a subset of the complete game structure that employs game technology for a less-interactive purpose to complement traditional approaches of lesson delivery. The structure primarily is designed to support two instructional events; presenting stimulus material and providing guidance through a machinima approach. Real-time animated movies are used as illustration to complement the traditional approach of lesson delivery and can either be interactive or non-interactive depending on the component used. Other instructional events not covered in this pedagogy structure will be carried out by domain experts using their preferred approaches. Learning contents created using this structure follow the flow presented in Figure 4 that functions as a video presentation.

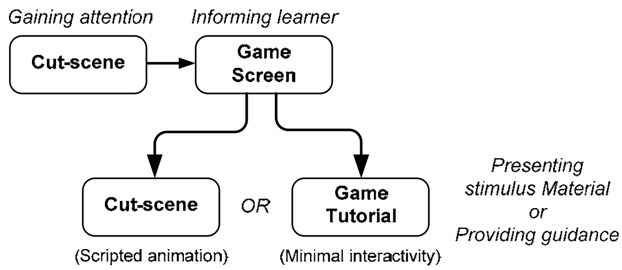


Figure 4: Presentation-based structure for serious games.

*Food Force* is a serious game commissioned by the United Nations World Food Programme (WPF) that educates learners between the ages of 8 – 13 about the fight against world hunger in a fictitious island through six different missions with specific learning objectives; *Air Surveillance* - The causes of hunger and malnutrition; *Energy Pacs* - Nutrition and the cost of feeding the hungry; *Airdrop* - WFP's emergency response; *Locate and Dispatch* - Global food procurement; *The Food Run* - Land-based logistics; and *Future Farming* - Long-term food aid projects [38]. Because the intended audience are mostly children, most of the learning contents are presented via cut-scenes and as a reward children get to play mini-games with simple and straight forward interactions. In *Air Surveillance*, learners are briefed on the mission about the importance and purpose of aerial assessment and are expected to use the mouse to navigate a helicopter around an island to spot for hungry people by simply moving the mouse cursor. Learners have to cover as much area as possible within 100 seconds.

### 4.2.3 *Training-based structure*

Training-based structure basically guides learners to use or operate certain objects such as tool and machinery that in reality might be considered dangerous or costly for training purposes. It can also be used to provide training on the standard procedures of a task. Training-based structure extends the presentation based structure to include more in-games components with relevant physics systems and artificial intelligence capabilities. The training-based structure is presented in Figure 5 where cut-scenes used to present the stimulus are optional.

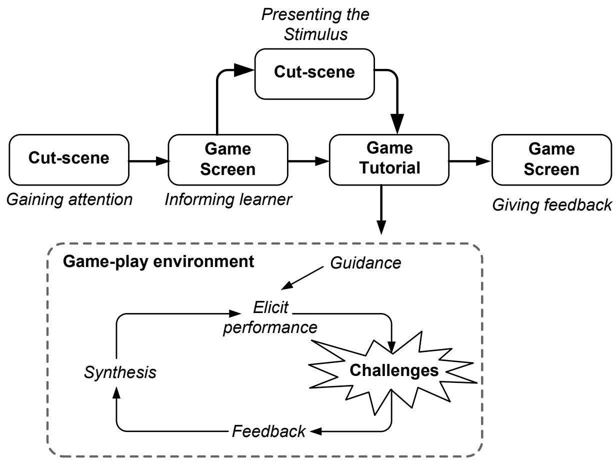


Figure 5: Training-based structure for serious games.

### 4.2.4 *Scenario-based structure*

Scenario-based structure is based upon the representation of a single scenario reconstructed to reflect reality involving characters and objects in a virtual space. It is a stripped down version of the complete game structure that consists of only *one scenario* instead of multiple scenarios. Learners are expected to apply the knowledge and skills they have learnt either from serious games or from classroom lessons in the scenario to solve problems defined in the scenario. It possess similar characteristics to the training-based structure except that learners are not guided in performing tasks and solving problems. This structure is ideal for learners to experiment their solutions and for domain experts to measure and access learners understanding toward the area of study.

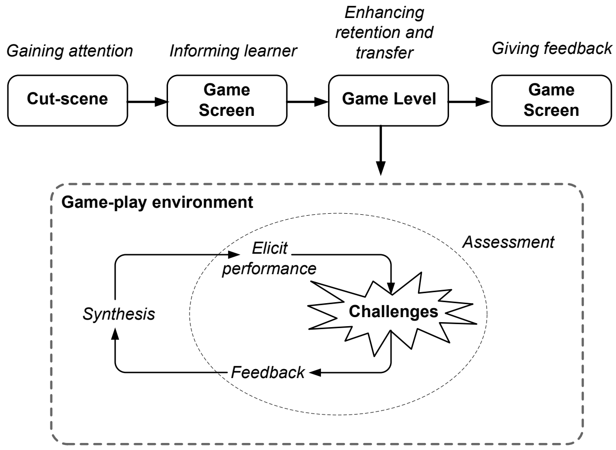


Figure 6: Scenario-based Structure for serious game

The multi-user mode of America's Army consists of missions that are playable by learners only after they have completed the necessary trainings in the single-user mode. These missions are designed with scenario-based structure that brief learners on the objectives of the mission and challenge learners to work and strategise in teams within the hostile environment. These missions are played over the network where learners are divided into two opposing teams; assault and defence. *Border* is one such mission that places learners in a small border village where the assault team are required to secure precious cargo and a specific location and then proceed to an extraction point while the defence team are expected to defend it [36-37].

# 5. AUTHORING ENVIRONMENTS FOR SERIOUS GAMES

## 5.1 Objectives of an authoring environment

Our initial research study on digital game-based learning attempted to integrate learning theories into the design of serious games [32-33] and has led us to realise a major barrier pertaining to digital game-based learning; the source of serious games. Development of serious games may require a huge budget and such financial barriers have been a major challenge for many domain experts who intend to adopt such educational technology. In fact, most of the serious games are either developed in house by a team which has skills and knowledge in programming interactive graphics or outsourced to professional game developers. Many domain experts who wish to adopt such educational technology have tried sourcing for such content from commercial-off-the-shelf (COTS) tools, however it is rather difficult to source serious games which could be used directly in learning as most commercial digital games are designed specifically to entertain and many even elicit violence and sexual content, thus rendering them inappropriate for use in some education and training context [32-33]. Such a challenge should be addressed to further encourage the use of digital games for non-entertainment purposes.

Developing serious games using open source or royalty free game engines such as Panda 3D [40] and Torque Game Engine [41] is rarely an option to be considered as it demands the knowledge and experience of a experienced game developer who knows how to exploit such technology for specific usage and also art assets to be produced by game artists. Integrated game development environments such as GameMaker [42], Adventure Game Studio [43], Squeak [44] and XNA Studio [45] provide an extensive library of code for development of digital games, however it still requires programming knowledge which challenges most domain experts who intend to port their knowledge for use in digital game based learning. Alternatively serious games can be created through 'modding' (modifying) COTS games by means of utilising a game editor application (an in-house built tool used by professional game designers to create game levels but made available for enthusiast game-players to create customised items, characters, enemies, models, modes, textures, levels, story lines and game modes). However, modding requires a substantial amount of knowledge of the technology behind the game. Although there is a list of commercial games that offers such a facility officially or via third party tools, game engines are architected for very specific purposes that may constrain the type of serious game that can be produced [39].

The new generation consoles such as Microsoft's Xbox 360, Sony's Playstation 3 and Nintendo's Wii open up a whole new dimension for development of immersive and innovative content but are only accessible to a select few game developers. At present, game developers are the key to digital game based learning but are available in such small numbers in relation to the number of domain experts who wish to produce serious games for use in training and education. It is clearly noticeable that development of serious games requires professional expertise which is costly. In order to accommodate mass adoption of digital game-based learning, development of serious games should be partially automated by software while providing the flexibility to domain experts to author major aspects of the serious game and therefore reducing the technical and financial barriers for adoption.

## 5.2 Using pedagogy elements, components and structures in an authoring environment for Serious Games

Serious games are made up of user interfaces and in-games components that are programmed using game engines according to the design specifications and organised in a structure to represent the model of the game experience envisioned by the game designer. In general, a game engine is a collection of application programming interfaces (API) that are logically grouped into its own classes as software components that can be used to represent the user interface and in-games components in software environment.

At a higher level, game developers may use the scripting facility in the game engine to program game screens, scripted real-time animation, game tutorials and game levels. Such a scripting facility can be encapsulated within an authoring environment that hides the complexity of game development from domain experts. The existence of such a software tool would help in reducing the barrier for most domain experts who intend to adapt digital game-based learning as a modern and innovative approach for knowledge transfer. It allows practitioners to focus on their creativity in designing exciting serious games while the software tool would take care of all the technical aspects of game development.

Pedagogy elements, components and structures of serious games described in Section 2, Section 3 and Section 4 are items that domain expert should consider when designing a serious game. Identifying each of these items and presenting them as pedagogical items may help domain experts to quickly adapt themselves to the software environment even with limited knowledge on serious games development.

Ideally authoring environments should be programming-free and user-friendly to assist domain experts in developing serious game content. They should allow domain experts to create serious games easily via a user-friendly task definition and modelling environment that acts similarly to game editors used by professional game designers but with less technical knowledge required. We have identified a core set of requirements for a serious games authoring environment which includes features not limited to *graphical user interface* (GUI) *based definition and modelling environment*, *separation of art assets and technical codes*, and *automated code generation*.

The software tool generally acts as a collection of user interfaces that gather necessary information about the serious game from practitioners through graphical modelling and definition of components. In brief, the GUI-based modelling environment enables the practitioner to construct cut-scenes, game tutorials and game levels by arranging the defined in-games components in a virtual space. Other interfaces allows the practitioner to specify the use of art assets, assign behaviours to actors and objects, define interactions, define flow and structure of the game, define the user interfaces and other relevant components. Information gathered via the user interface will then be interpreted and translated into software codes via an automated code generation facility can be targeted toward a specific development platform(s) or specific game engine platform. Art assets and software code can then be compiled as an executable that represents the serious game as a software application.

Art assets and technical components that represent actors and objects in serious games should be created by experts in game development to eliminate the complexity in each area and thus allowing the domain expert to focus on the task of designing the actual problem scenario. Such an approach allows serious games software to be properly created while allowing domain experts the freedom to author such interactive content to their needs. These art assets and technical components can be imported and organised in a library supporting an expanding collection of art assets and behavioural functions, actors and objects. Having such collections of art assets and technical components provides the opportunity for domain experts to reuse these components to define (and re-define) actors and objects of various identities to populate the virtual space that may result to reduction in cost of development for serious games.

# 6. CONCLUSION

In this paper, we have presented our definitions of pedagogical elements, components and structures for serious games taking a pedagogy perspective to provide insights to domain experts on those parts of digital games which can be designed to provoke learners' interest and facilitate knowledge construction. Dissecting digital games and studying their pedagogical values provides us with the most fundamental example of how learners learn through a cause and effect learning principle embedded within virtual actors, objects and their interactions. Learners are able to derive meanings from these embedded relationships and apply knowledge effectively in the virtual environment to perform tasks and solve problems. Understanding and using the pedagogical elements, components and structures effectively can present a huge advantage over traditional didactic or instructor-led pedagogy that 'tell' learners but are somewhat lacking in the 'show' aspect. Our proposal of serious game structures in Section 4 encourages the use of serious games on a smaller scale for different purposes and not to be confined by the traditional game structure so as to take advantage of such innovative educational technology in delivering lessons that motivates active learning.

Our definitions are merely part of a larger framework that we are working on to support the development of serious games via an authoring environment. Our descriptions of authoring environments provide some key aspects for consideration so that fellow pedagogues can devote themselves in the process of designing without worrying about the technical aspects of serious games development. We envision that such an authoring environment would allows domain experts to define the properties, behaviour and relationships of in-game components, arrange them into a virtual space and define a set of tasks to form a problem that invites learners to solve problems easily through assistive user interfaces while automating the generation of software code for the serious game by interpreting the information gathered in the authoring environment. These activities may not be the norm for many domain experts, but underlying these activities are the tasks of lesson design in serious games.

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