ONTOLOGY OF SERIOUS GAMES

By

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ABSTRACT

Computer games are no longer just for entertainment; they have also become a useful instructional strategy for acquiring knowledge. When games are used for purposes other than strict entertainment they become serious games. The goal of serious games is to enable the player to learn a task, master a strategy or develop a skill. Serious games can be used for education and training in any organization, including military, K-20 education, business and industry. The application of serious games in a wide arena requires an ontology for designing high-quality materials.

Keywords: Games as instructional strategy, serious games, ontology, ontology of serious games.

INTRODUCTION

Games have entered the instructional strategy world as a valuable tool that can be used to engage learners. Games have been used for education and training in many ways for multiple content areas, using a variety of strategies. Effective, efficient and meaningful games that are serious in nature, provide educators a valuable resource that they can use it to promote performance and motivation. From pure entertainment to the notion of a game with educational focus, games have emerged as a way to engage learners. Design of a serious game requires a comprehensive ontology to focus efforts and development of the end product. This paper presents such ontology and is organized into four main sections: essential characteristics of a learning environment, essential characteristics of games, games as an instructional strategy and ontology for serious games.

The ontology for serious games described in this paper is a result of research in formalizing a design for educational (serious) games to teach middle school mathematics in the context of career themes. The researchers involved in this activity included faculty from the University of West Florida and personnel from the Escambia County School District who were awarded a Math and Science partnership grant by the Florida Department of Education in 2007 to develop serious games that integrated Algebra concepts within a career-related scenario or context. The framework developed for the design of the games culminated in the design of this ontology. A definition of games and serious games is provided to establish a context for such an ontology.

Defining Games

Games are a fundamental aspect of human existence and are contextualized and defined by the player. Some researchers define games through processes such as play, rules, and competition (Salen & Zimmerman, 2003). Wittgenstein (1953) proposed that it is not possible to have a single definition for the concept "game." He suggested defining games as activities with rules, play, or competition all fail to adequately define the term game. Others (Crawford, 1997, 2003; Kramer, 2000; Salen & Zimmerman) have tried to define games based on semantics, emotions, and rules. Kramer documented that in the German language a game is any activity which is executed only for pleasure and without conscious purpose. In this definition every activity that brings pleasure is a game (Kramer). Crawford suggested that games are scenarios which have rules and provide equity. However, the aspect of learning seems to be implicit in the definition of the term game. Every game requires that the player learn and master rules to play the game and win, which means that games are inherently

educational, although the purpose and the intent of the player may not, in fact, be one targeted to learning (Crawford, 1997). For the purpose of this paper, games will be defined as enjoyable and entertaining educational activities that involve rules, challenge and interactivity (Salen & Zimmerman).

Serious Games

Serious games are serious business, contributing to an economy of $2 trillion in the global market towards education and government sponsored training (Susi, Johannesson, & Backlund, 2008). Michael and Chen (2006) define serious games as games that "do not have entertainment, enjoyment, or fun as their primary purpose, … [that] use the artistic medium of games to deliver a message, teach a lesson, or provide an experience" (p. 21). This definition does not mean to imply that serious games do not have entertainment value; in fact, the *Serious Game Showcase and Challenge* (cited in Susi et al.) specifically identifies challenge, along with reward systems and feedback, as critical elements of a serious game.

However, there are other purposes to a serious game, specifically, education within an entertainment context. Serious games are designed with a purpose and a focus for a specific audience. Serious games are those games that help to develop a skill, learn a language, or acquire concept knowledge. Examples of serious games designed for a specific audience include (a) those designed for the military which contain training modules focused on warfare strategy, (b) opportunities for surgeons to develop specific skills for specific surgeries, (c) those that provide educational content (Susi et al., 2008). The applicability of serious games is wide and strategies for designing and developing serious games (including an analysis of a learning environment and the gaming world) are needed to facilitate a successful experience for designers, developers, and players.

Essential Elements of a Learning Environment - Theoretical Perspectives

Several theories for the design of learning environment such as those found in games have been advocated based on theoretical foundations of learning theories including behaviorism, cognitivism, and constructivism. Common elements applicable to the ontology of serious games in these theories include motivation, contextual relevance, challenge, scaffolding, student engagement and feedback. Context, through authentic learning environments, provides a framework for serious game development. Instructional design models (e.g., Gagné's (1985) nine events of Instruction, Keller's ARCS model, Malone's Motivational model) provide ways to incorporate resulting instructional strategies to enhance instruction.

Motivation promotes a desire and curiosity to participate and explore the educational content. Malone (1981) suggested that "if students are intrinsically motivated to learn something, they may spend more time and effort learning, feel better about what they learn, and use it more in the future" (p. 335). Motivated students can then have an exciting learning experience (Smith, 2006) which, in turn, should be relevant to their own learning needs. Relevance can be characterized by how material satisfies the needs of the user and is applicable to a particular situation. Keller's (1987) six strategies for relevance include (a) experience (b) present worth (c) future usefulness (d) needs matching (e) modeling and (f) choice. Challenge is a powerful intrinsic motivational factor. Malone and Lepper (1987) described challenge as a situation with clear goals that are relevant to the student that require a response.

Gagné's (1985) events of instruction are framed around the notion that elements of instruction should include techniques to assist learners in acquiring attention, being informed of objectives, recalling information. Then, instructors or teachers design the environment where they present content, provide guidance, elicit performance, and assess performance. Throughout the learning process, feedback is provided to ensure that the learner progresses appropriately through the instruction. At the end of the lesson, strategies are put into operation that enhance retention and help the learner to transfer the acquired knowledge to application. A learning environment that incorporates these nine events and is

challenging will stimulate the learner's curiosity and motivational levels to aspire and reach higher goals (Collins, Brown & Newman, 1990).

Another foundation, student engagement, is equally as important to the learning environment. Levin (2005) found that engagement in learning involves the abilities to be a self learner, to explore, to set and assess goals, to transfer learning, to creative problem solving, and to participate in collaborative activities. Jones, Valdez, Nowakowski, and Rasmussen (1994) found that student engagement plays a vital role in the process of learning. Reflection and action are critical components in the construction of knowledge and it is difficult to extricate one from the other (Caine & Caine, 1991; Freire, 1973). Freire believed that reflection promotes critical thinking and learners become actors and not observers and authors of their own decisions.

The theoretical foundation provides the game designer with a framework by which to structure essential elements of a game. This framework provides insight into how players will interact and, hopefully, learn, from the serious game.

Essential Characteristics of a Game

All games should be comprised of essential characteristics to provide enjoyment and pleasure to the audience (Bateman & Boon, 2005; Novak, 2008). These characteristics frame the boundaries of the game and set expectations for the design and development of the game. These characteristics include audience and narration, gameplay, fantasy, graphics, choices, challenge, immersion, and rules.

Audience/Compelling Narration

The goal of every game is to provide enjoyment to the audience (Bateman & Boon, 2005). Bateman and Boon suggest that focus group interviews and team meetings can assist in developing an engaging framework from which to start the design process. Designers must ensure that game scenarios include interesting stories and plots to engage the player and encourage curiosity and enticement. This combination facilitates an exploration of a world of fantasy. King (as cited in Novak, 2008) suggests that plot or story line and associated narration can determine the success of a game. Players of computer and video games such as *Commandos 2: Warriors of Courage* and *Arcannum* reveal that they perceive themselves as participants in the ongoing story and can adequately describe the story of the game that they are playing and also anticipate the outcomes of the story (Carlquist, 2002). Narrative strengths of games combine to produce even more immersive and enjoyable gaming environments (Lambert & Rider, 2001).

Game play

Fitts and Posner (1967) suggest that learning is a process of acquiring skills and displaying skilled performance. These processes are comprised of a string of organized activities. Organization, goal directedness and utilization of feedback form the core characteristics of a skilled performance. The journey of learning and mastering the strategy to reach the goal should include stages that increase gradually in levels of difficulty and complexity of rules. Retaux and Rouchier (2002) state that there must be a cognitive challenge in the discovery of the laws of the universe some of which are implicit and require training. An example of this type of challenge would be assessing and evaluating if a bridge can be crossed or jumped over in a given scenario. These challenges and complexities are what make the playability of a game interesting.

Gameplay includes interactivity. Games are distinct from many other types of art, such as listening to music or watching a painting or a drama. Although all these forms of art provide pleasure and enjoyment, they engage as an observer, not as a participant. Games, on the other hand, are inherently interactive; even games designed for individual play like puzzles are interactive since the individual does something that produces an effect. Games allow the player to explore the environment, participate and interact with it, make decisions, and observe transformations in a make-believe world.

Fantasy

The element of fantasy distinguishes a game from a simulation. A simulation is a representation of something real, for example the working of an aircraft, atomic

structure, surgical procedure etc. Simulations are also usually designed for computational or evaluative purposes. (Crawford, 1997). Games, on the other hand, include an element of fantasy or fiction in addition to its realistic components (e.g., buildings, characters, terrains) (Crawford) and are designed for entertainment purposes. But these characters or situations need not correspond to real persons, animals, buildings, etc. A person can be an alien, an animal can be a robot and a building can be in the shape of a butterfly. It is this aspect of representing reality through the artist's rendition with aspects of fantasy that transports the player from the real world to the world of fantasy and engages the learner in unfamiliar territory. Games like *Zork* and *Myst,* through the elements of fantasy, provide an engaging and immersive environment for the player (Novak, 2008).

Graphics and Level Design

High-quality, relevant graphics are important for a successful game, examples of games include *Doom, Quake 3 Arena* (Hardwiger, 2000), and *Myst* (Novak, 2008). They constitute a necessary condition for the 'Net genners' who grew up with an exposure to computers and digital media (Oblinger 2004; Prensky, 2005). Although high-quality graphics are not a sufficient condition for a good game, or in other words, quality graphics do not, in and of themselves, make a game successful (Erick, 2006; Peney, 2008). Other elements such as gameplay, narration and fantasy are important for a successful game.

Level design includes the creation of environments, scenarios and missions to be accomplished in a game (Novak, 2008). Additionally it also includes determining the time that a player should spend on a particular level. A general rule seems to be that a player must be able to complete one level in a session to maintain the tension and interest in the game (Novak). This level perspective approximates to fifteen minutes for children and two hours for gamers for computer games and upto forty-five minutes for a console game (Novak).

Choices and Decision Making

The gaming environment presents the player with situations and scenarios involving the application of higher-order thinking skills by requiring decision making. Kellar, Watters and Duffy (2005) reported that gamers preferred games with choices, since it provides the player with a sense of control over the environment. Examples of these games include Role Playing Games (RPGs) like *Lost Odyssey* and *Civilization*. RPGs allow the player to assume roles, execute decisions and experience the outcomes of decisions in a fictitious world, one different from the real world. Such experiences can, in a sense, provide positive social and emotional impacts on learners as the player has (a) learned to interact with real life scenarios such as deliberating and deciding on one set of actions vs. another and (b) experimented with strategic planning activities involving allocation of game resources in a fictitious environment and experience the consequences through rewards and or penalties without real world hardships. These elements facilitate the player entering a fantasy environment, strengthening another element of the framework.

Challenge and Tension

Engaging games must also include challenge and tension as a way to retain player interest. Challenge and tension can be encouraged through the use of elements such as distractions and attention focusing strategies. A good game must have frequent changes in flow of the game, peaks and dips to deliver challenge and tension (Kramer, 2000).

Immersion

The most interesting aspect of games is that they create an immersive environment for the player. Immersion is an aspect of games that is rated highly by game designers, developers and players (Brown & Cairns, 2004) and makes the player a participant in the environment. Several aspects of the gaming environment contribute to this immersion including intricacies (e.g., realism, sound effects and depth) woven into the game, elements of fantasy, challenge, story line, and tension. Such immersion contributes to the player's enjoyment - a primary goal of the game and ensures replayability (Kramer, 2000).

Rules and Feedback

Setting clear goals and feedback is necessary for a player to participate and progress in a gaming environment. Games must have clear instructions to help the player understand the rules of the game; rules must be equitable (Crawford, 1997; Novak, 2008). Feedback is usually offered through rewards and penalties in games. Fullerton (as cited in Novak) stated that creating meaningful and interesting choices is an important challenge for game designers. Positive and negative reinforcements and feedback provide the necessary motivation to make modifications of skill sets that allow the player to continue the game (Burgos, Van Nimwegen, Van Oostendorp, & Koper, 2003).

Games as an Instructional Strategy

It is not surprising that games can be used as an instructional strategy, since games are inherently educational in that every game requires mastering a skill to win (Crawford, 1997). Jones (2003) and Oblinger (2004) indicated that nearly 60% of students in the age group of six and older ('Net genners and millenials [born since 1980]) play computer games. Integrating computer-based or video games into a learning environment scaffolds students from using video games as recreational activities to using games as educational materials. Students are attracted by video and computer games, and educators have the opportunity to take advantage of manipulating gaming environments for instructional purposes. Through the use of games educators can create an exciting and motivational instructional environment by including elements of imagery, challenge, experimentation through role play and feedback, all essential to successful learning, and, in turn, defining elements of a serious game.

Oblinger (2004) further observed that the 'Net genners' had the following characteristics: (a) they gravitate toward group activity (b) believe that it is cool to be smart and (c) are fascinated by new technologies. This student population is not intimidated by technology; they believe in using technology to its fullest potential and respond positively to technology-mediated instruction including video and computer games. The challenge for instructional designers is to use the myriad of available technologies to design an engaging and stimulating learning environment. Experimental use of serious games to motivate children to learn include the use of PlayStation games to teach fundamental math concepts in Britain (Macmillan, 2006). Dede (2005) found that the gaming environment is beneficial for unmotivated, failing students and observed that students who are distracted and cannot concentrate on instruction can be highly focused and motivated to complete a task when engaged in games.

Games must be contextualized in situations, plots, and for serious games, on academic standards. Educators are searching for ways to prepare students to lead the way in inventions and innovations. During the development of the game ontology, that is the subject of this paper, a set of serious games were designed where the contextualization was a combination of STEM subjects (Science, Technology, Engineering, and Mathematics) and Careers. The objective of the challenge was to design a game where students could innovatively resolve problems while they built foundational knowledge and skills related to career awareness and the use of Algebra. A group of faculty, school district content experts and career specialists defined and used the ontology presented to develop tools to engage students in career and math and science concepts for the purpose of improving performance and practicing critical thinking skills in math, science, reading and writing all using an gaming instructional approach integrated into the middle school classroom.

The instructional strategy of gaming can promote skill development in the following areas: critical thinking, control, engagement and feedback. In addition gaming can help students see relevance of situations to their own environment and learn strategies to work in a self-paced environment.

Critical Thinking and Problem Solving Skills

Games are a creative teaching strategy that enhances learning and problem solving. Gaming strategies are

being used by the authors to make learning interesting, stimulating and fun in middle schools. Van Eck (2006) suggests the use of several commercial off the shelf games in higher education, including *Simcity2* and other adventure games which are open ended for hypothesis testing and problem solving; games such as *CSI* can be used to teach forensics.

Control

Control and reflection are other critical elements in the learning process (Caine & Caine, 1991; Freire, 1973). Control is defined as a feeling of self-determination on the part of the student (Malone & Lepper, 1987). Providing students the ability to control their learning environment is in itself a motivation that helps learning (McLeod, 2006). McLeod maintained that video games provide opportunities for gamers to be the producers of knowledge, not just consumers. In addition, video and computer games also provide students with scenarios that require reflection (Anderson, 2004). Control can also involve elements of reflection. Reflection provides the ability to act and transfer knowledge to unfamiliar territories and further acts as a motivational factor for the student because the student experiences the fulfillment of a successful transference of knowledge (TAP, 2000). The gaming scenario provides opportunities for students to take control over their actions and reflect upon the strategies employed in a particular game.

Student Engagement and Motivation

Computer games provide engagement, which is why people want to play these games (Jones, 1997). Jones suggests that since games offer participant engagement and interactivity, games can be a good instructional delivery system. Games allow the student to interact with the game world by manipulating the variables and experience the effects of these manipulations (Jenkins, 2005), thus engaging the student in play.

Feedback

A major roadblock that students face is the lack of confidence on their journey to learning. A gaming situation is an ideal candidate to create a platform for boosting confidence through feedback mechanisms. Playing at their own pace, players gain familiarity with the setting, which increases their self esteem (Dempsey, Lucassen, Gilley, & Rasmussen, 1994). The setting is secure because there is no external pressure, and the player creates and develops a comfort zone from which to navigate and participate in the game. Mitchell and Savill-Smith (2004) observed that the gaming scenario can provide prompt feedback, an essential element of a good instructional strategy (Chickering & Ehrmann, 1996), through game elements such as a score card and messages related to progress and answers to questions. Feedback can be advantageously used in creating instructional materials within a gaming environment in two ways:

1. Motivate the student by providing hints, suggestions, and examples to steer the student in the right direction towards learning.
2. A reporting feature which provides accountability for teachers and parents for the time the child spent in a gaming environment. Typically reporting should include the cumulative score, time spent by the student on each question, the bench mark or other type of standardized information to identify the topic being tested. Additional features could include e-mailing the score to the teacher or parent of the ``` student for recording purposes, and maintaining grade books. Figure 1 is an example of a report generated by the Math Matters games.

Contextual Relevance

Oblinger (2004) and Prensky (2005) also note that computer and video games provide the context that

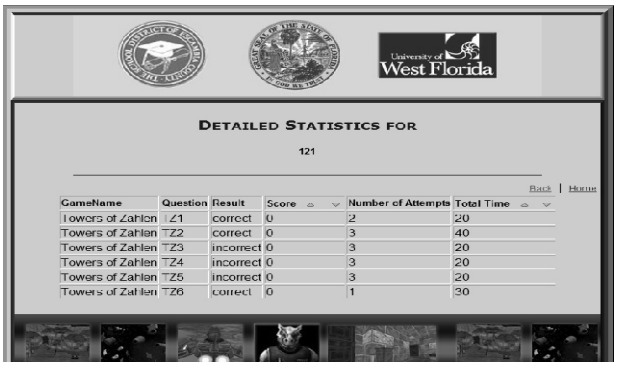

Figure 1. Report from Math Matters game

students can relate to, since it is an environment that they are constantly engaged in and are not intimidated by. In fact as pointed out by Klassen and Willoughby (2003) the gaming world can be used as a motivational factor to promote learning. Consequently, the gaming environment can be used as a strategy to have a captive audience for instructional purposes.

Self-Paced Learning Environment

Oblinger (2006) and McLeod (2006) maintain that a computer gaming environment can provide a self-paced learning environment that is advantageous to both the student and the instructor. Students usually shy away from approaching the instructor for further explanations on a concept, but the gaming environment provides an alternative pathway, allowing the student to learn concepts by replaying a section of the game any number of times. This self-paced learning environment also frees up the instructor time to help other students who prefer instructor help. Connolly, Stansfield, and McLellan (2006) mention that a virtual tutor or an e-coach provides coaching/feedback through hints and is extremely important in serious games. Such feedback and guidance help students develop abilities of reflection and scaffolding (Collins et al., 1990).

A Proposed Ontology for Serious Games

Ontology is defined as "[A] classification of the types and subtypes of concepts and relations necessary to describe everything in the application domain" (Sowa, 2000, p. 454). In a series of research and development efforts, catalogs of gaming and learning environments elements that facilitate and promote performance and, motivation have been designed, developed, implemented, and evaluated. From the two catalogs, a third catalog was designed: a serious gaming environment protocol which links the elements in gaming and learning environments. This protocol led to the development of an ontology that provides designers of educational games and other serious game developers a framework for creating serious games. A sample design of a game with the proposed ontology is presented here.

The ontology for serious games is a marriage between the gaming environment and the learning environment. Ideally this ontology should include all of the concepts previously discussed as essential characteristics of a game comprising the first catalog, and a learning environment comprising the second catalog. The third catalog is the ontology which merges the concepts from these two catalogs and concepts inherent in serious games. The methodology used to construct this ontology is to map the correspondence for the elements in each catalog and provide a strategy to address the correspondence in the serious games column. Table 1 is the resulting ontology, IDEAS Pro. The ontology can be implemented into a game design and development project by using traditional instructional design processes

Games – Essential Elements (Catalog 1)	Learning environment – Essential Elements (Catalog 2)	Serious Games- Essential Elements (Catalog 3)
1. Audience	a. Audience and Learning outcomes	Identify and Design for a specific Domain / Audience with appropriate learning Outcomes
2. Gameplay	b. Instructional Strategy to deliver content including goals, objectives etc	Determine Instructional Strategies to be embedded in a game environment
3. Narration / Immersion	c. Student Engagement	Establish Story line and build contextual relevance for instructional content in an Immersive environment
4. Challenge / Tension	d. Challenge / Scaffolding, Reflection	Apply Instructional strategy to story line and provide challenging scenarios to encourage Reflection
5. Rules / Feedback	e. Feedback	Set and design scenarios to promote critical thinking, Reflection and include feedback mechanisms
6. Fantasy, Graphics, level Design	g. Attention / Motivation	Production phase - Design an enticing environment with rich media effects that attracts student attention and provides motivation.

Table 1. Ontology of Serious Games: IDEAS-Pro

and principles. These processes and principles include application of learning and instruction theory as the product is designed, developed, implemented, and evaluated. This process, formalized as IDEAS-Pro, is outlined in Figure 2.

In the IDEAS-Pro system, learning outcomes are identified, using needs analysis and academic standards data. From that point, instructional strategies, the type of game to be designed is selected. The plot, or story line, is then established. Extensive storyboards are used to make sure that standards, content, and story are aligned. Finally, the production begins (the *Pro* in IDEAS-Pro). The cycle is iterative and includes both formative and summative evaluations. An iterative, concurrent system becomes the norm where decisions are revisited and revised as the ontology is put into practice. In Table 2, the application of IDEAS-Pro to a serious game *Providers*, a game designed to teach algebraic concepts for 7th and 8th graders is presented (Prayaga & Rasmussen, 2007). Figures 3 and 4 are game assets from *Providers* used as trading cards similar to the popular toy trading cards like Yohijo that students can exchange as they go through the different game levels during the semester.

Conclusion

In this article we have provided an ontology which was found in theory from both the academic and the entertainment (gaming) worlds. The application of the IDEAS-Pro ontology to game development provides a framework or structure by which designers and developers can create serious games that meet the requirements of the education or training situation as well as the entertainment needs of the player. In environments where performance is the ultimate objective, merging the essential game elements with a strong theoretical foundation greatly improves chances for successful serious games.

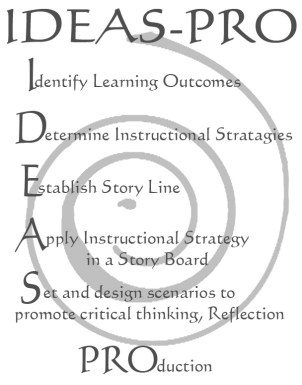

Figure 2. Ontology Framework

Figure 3. Avatar (female) Pilot in trading card format.

Figure 4. Spaceship in trading card format.

Identify Audience (7th & 8th Graders) / Narration/ Game Summary Providers	Determine Instructional Strategy / ARCS/ MALONE Elements	determine Instructional Strategy Goals and Outcomes / SSS Benchmarks	Establish Contextual relevance /Career Cluster/ Related Career Fields STEM	Establish Contextual Characteristics (Aligned Knowledge, Skills, Abilities	Apply Instructional strategy to story line /Roles of Avatars & Non-playing Characters (NPC)	Set and design Sample Activities in the game to reflect Math Examples (Type of Assessment)	Supporting Materials Video Support
Simulation where the members of an elite group called the Providers must collect fuel cells found at mathematically coded locations in the galaxy and successfully bring to the reactor which is desperately low on fuel cells. Player chooses an avatar and cruiser before departing on mission. Each level introduces different coordinate locations, equations, and navigation obstacles.	Gain attention through student activity (Steering aircraft) Activity is located in a fantasy world. Motivates the student, arouses his / her curiosity to explore the game	Learning outcomes: Student identifies each quadrant and the characteristics of points in each quadrant (positive and negative	Aerospace Pilot, Copilot and Flight Engineer	Steers aircraft along planned routes with the assistance of autopilot and flight management computers	Commander: Sets the scenario stage, explains the problem. Establish the role of participant in problem-solving the scenario. Participant plays role of captain and chooses one of the following avatars to represent character Avatar 1: human male Avatar 2: human female Avatar 3: alien furry creature Avatar 4: alien muscular creature NPC- Navigator/ Radiotransmitter NPC- Leader of the Federation NPC- Commanding Officer	The cruiser is at position (x,y). In what quadrant is it located.	Opening overview of game, with power expert explaining the purpose of the game and detailing the uses of math as part of the game. Establishes the environment, context, and overall goal. Summary at end of each level, recap of progress, motivation to next level, reiteration of the math processes explored.
	Provides Relevance for mathematics, because the game scenario requires the student to go to allocation given the coordinates. Motivates and Challenges the student to complete this task to proceed further into the game.	Example Benchmark From: Florida SSS MA.D.1.3.2 Interprets and creates tables, function tables and graphs (all four quadrants	Aerospace Engineering and Operations Technicians	Uses mathematics to solve problems		The first fuel cell is at coordinates (x, y). The formula for the distance from the origin is d $= \sqrt{x^2 + y^2}$ The distance to the first cell is approximately,	

Table 2. The Providers (A serious game designed using the proposed ontology of serious games)

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