# Enhancing the Educational Value of Video Games

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Lowering the barrier between education and real entertainment is an important challenge in order to better exploit the potential of computers and reach a demographic that is traditionally averse to learning. To this end, it is important to investigate how to exploit the appeal of video games (VGs) to also favor and induce learning via playing video games. Achieving this goal is not only a matter of content, since simply "superimposed" educational content risks being perceived as boring. Hence we believe that the game should feature mechanisms for acquiring knowledge and skill that are smoothly embedded in a meaningful, homogeneous, and compelling whole.

Thus, there is a need to compartmentalize components of a game engine so that it becomes easy and efficient to integrate the graphics/interface—which has already been done very well by state-of-the-art successful video games and the educational aspect which is typically poor in those same games. Hence we have defined a general set of mechanisms and modules that can be inserted in state-of-the-art VG environments and are aimed at promoting various kinds of knowledge and procedural skill acquisition.

In order to investigate and validate this concept, we have built an educational game, *SeaGame*, using a state-of-the-art commercial game development approach, and enriched the environment with instances of developed educational modules.

Analyzing user test results, we conclude that *SeaGame* is perceived quite similarly to commercial VGs, which suggests that the proposed mechanisms do not compromise the overall enjoyability of the game, which is key to attracting a wide demographic that is not currently involved in educational activities during their leisure time.

The results of this research can be generalized, since the standards of commercial games and the proposed educational enhancements can be instantiated in a variety of educational contexts and applied to different types of content.

**23**

Categories and Subject Descriptors: K.8.0 [**Personal Computing**]: General—*Games*; K.3.1 [**Computers and Education**]: Computer Uses in Education—*Computer-assisted instruction*

General Terms: Human Factors, Measurement, Performance

Additional Key Words and Phrases: Serious games, video games, educational games, constructivism, repertory grid technique, virtual worlds, technology enhanced learning, video game test and evaluation

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DOI 10.1145/1541895.1541903 http://doi.acm.org/10.1145/1541895.1541903

**ACM Reference Format:**
Bellotti, F., Berta, R., De Gloria, A., and Primavera, L. 2009. Enhancing the educational value of video games. ACM Comput. Entertain. 7, 2, Article 23 (June 2009), 18 pages.
DOI = 10.1145/1541895.1541903 http://doi.acm.org/10.1145/ 1541895.1541903

## 1. INTRODUCTION

The research community has become ever more interested in investigating tools and methodologies to support learning through video games (VGs) [Zyda 2007]. In fact, games have always been a powerful mediator for learning [Rieber 1996], and computers can provide added value in terms of real-time interactivity, immersiveness, personalization, and knowledge-basis. However, analyzing the VG market—one of the most flourishing industries in the world [Carless 2005]—we see that successful games offer complex experiences for players, feature beautifully rendered characters and landscapes, and show ever more realistic animations, but have very little, if any, educational purpose and value.

On the other hand, educational games are still a niche market and are not widely successful, since they are often perceived as boring. They rarely use state-of-the-art effects and techniques, and/or are quite specialized. This last case is typically one of the *serious games* [Zyda 2005] that provide highly realistic 3D simulation environments and are successfully employed in training for areas such as government [Raybourn et al. 2005]; health [Sliney et al. 2008]; the army [Losh 2005]; science [Mayo 2007]; and corporations [Michael and Chen 2006].

Thus, lowering the barrier between education and entertainment is an important challenge to the effective exploitation of the potential for computers to reach a demographic that is traditionally averse to learning [Prensky 2003]. To this end, it is important to investigate how to exploit the appeal of VGs to favor/induce learning in an audience that does not play games in order to learn. For example, players may be attracted by the entertainment features of the game and during the game they could develop knowledge and procedural skills in a meaningful and compelling way.

This scenario opens new, powerful perspectives to pedagogical experts and game designers, and has an important societal value, considering the ever growing need for life-long learning.

Achieving such a goal is not a matter of content only, since educational content that is simply "superimposed" risks being perceived as boring. We believe, instead, that the game should feature knowledge and skill acquisition mechanisms that are smoothly embedded as a meaningful, homogeneous, and compelling whole. With this perspective, our research aims at culturally enhancing existing games rather than decorating traditional educational exercises with game features (e.g., score competition, graphic effects, jingles). We are interested in studying mechanisms, procedures, and modules that can be inserted in a commercial-like game in order to effectively support education. To this end, we have developed a 3D game environment (*SeaGame*) that exploits state-of-the-art commercial game-engine technologies, and tried to enhance it through learning-oriented mechanisms.

Fig. 1. A snapshot of *SeaGame*.

In this article we discuss this approach, and also present results of user tests to assess its validity. Generalizing these results, we try to get insights and indicators that can be useful to researchers and practitioners interested in developing serious games that combine support for the acquisition of knowledge and skills and real entertainment for a wide public.

## 2. RELATED WORK

Research argues that computer games are an engaging medium for learning, since games can stimulate cognitive processes such as reading explicit and implicit information, deductive and inductive reasoning, problem-solving, and making inferences from information displayed across a number of screens [Zyda 2007]. Video games can be of direct educational value or, much more frequently, provide knowledge and stimulate skills as a side-effect [Pillay et al. 1999].

The idea of using virtual worlds (VWs) in computer games as educational media dates from the 1990's (e.g., ExploreNet Experiment [Hughes and Moshell 1997]). Today, with the increasing availability of PCs and wideband connections, online games can potentially reach enormous communities of would-be learners. Some virtual learning worlds (e.g. active world learning environments[1]) tend to mirror a classroom environment [Dickey 2003]. The social interaction enabled by online games can contribute to improving engagement, participation, and to maintaining a learner's interest [Corbit 2002]. Indeed, users feel more satisfaction in learning a topic if they are actively involved in it and are supported in developing relationships with other learners [Rovai 2002]. From this perspective, the success of massively multiplayer online games (MMOGs) via its powerful technology provides an important opportunity that could be exploited to support knowledge-acquisition by thousands of players [Ducheneaut et al. 2006].

[1]Active Worlds Inc. Active Worlds and Education, http://www.activeworlds.com/edu/index.asp.

The serious games research community proposes the use of such gaming environments for teaching and learning [Zyda 2007]. For instance, enhancements to game engines have been developed and used to teach some subjects such as foreign languages [Losh 2005] and safe road behavior [Bellotti et al. 2007]. However, commercial game environments have little flexibility in the structure of their virtual worlds and are not designed to address educational needs [Livingstone and Kemp 2006].

*Second Life* (SL)[2] is a very popular 3D virtual environment created by Linden Labs. SL is organized as a set of VWs structured as islands, where user avatars live through a variety of experiences. Several islands have been built and used for distance education, where students can also attend portions of courses at the university level [Ritzema and Harris 2008]. The OpenSIM project attempts to develop a similar environment, which can be run on any server and would be free of any "for-profit" commercial control.[3] Our approach is more specific: *SeaGame* is a credible 3D model of a learning situation and is developed on top of a commercial game engine enhanced with several learning tools (microgames, conversational virtual humans, events generator; described later). *SeaGame* stresses the importance of game believability to create a "sense of place" (through use of photorealistic 3D models, weather effects, surround audio, graspable virtual objects, natural lighting system, and so on) [Cartelli 2006], in which players can interact with the learning topic in a natural way [Fullerton et al. 2004]. If the player feels a "sense of place," he can experience the interactions, roles, and narratives more realistically and perceive the notions provided by the game as credible. The sense of place can be gratly enhanced by populating the VW with ordinary objects that the player could expect to find in real settings. Moreover, realism can be reinforced by allowing the player to interact with objects as in real life and by providing the same kind of outcome (e.g., if there is a jet-ski in the game, the player should know how to drive it). In order to improve the "sense of place," we also enhanced the game engine with conversational virtual humans (CVHs). CVHs are computer-controlled characters equipped with natural language dialogue that can be used to improve the learner's engagement in his activities [Wallace 2003]. The aim is to provide content, to introduce backstories, assign tasks, give feedback on user performance, and, more generally, offer information to the learner [Olney 2007].

## 3. SEAGAME

*SeaGame* is a massive multiplayer online game (MMOG) that was designed to promote best practices in sea-related behaviors. The target audience (but not exclusively) are high-school students, because typically people start engaging in sea-related tasks (e.g., sailing, motorboating, jet-skiing, doing beach surveillance) at approximately high-school age.

[2] www.secondlife.com

[3] http://opensimulator.org/wiki/Main_Page

### 3.1 Synopsis

On the *SeaGame* island a player can freely move in three major settings: a beach with a bathing establishment, a smaller free beach with a jetski center, and a tourist port with sports crafts and various types of boats.

The 3D world is persistent. The player can decide to access the VW at any time, starting from the status with which he had left. Day and night cycles and weather changes allow the player to live in a variety of situations and experience a number of challenges. For instance, the player may be at the seaside at sunset with a rough sea and the red flag hoisted to indicate danger. In these settings, the player can move freely with the goal of increasing his knowledge of the sea by exploring the various possibilities offered by the game.

Different tasks can be performed in different areas of the island, and to accomplish them the player has to follow some rules (e.g., to leave with the boat it is necessary to pass through a corridor, and jetski drivers have to keep a 200 meter distance from the coast). The system drives player exploration and test by inviting him to perform tasks like taking the jetski to reach the village port or to go to the beach and practice swimming.

*SeaGame* can be classified as a sandbox game [Squire 2008], with an open-ended and linear style of gameplay. The *SeaGame* player is involved in exploring the island, similarly to *Grand Theft Auto* (GTA), where the player wanders in a city, and to *Oblivion*, where he explores a fantastic world set in the Middle Ages. The entertainment is provided by strolling through the island's environments in which other players or virtual characters controlled by artificial intelligence (AI) live. A sandbox game's typical modality involves improving one's own reputation in order to become the best player in the arena. For instance, GTA is played in a context of urban gangs in which a player gains points by exhibiting anti-social behavior (robbing, killing). In *SeaGame*, reputation increases when a player demonstrates skill at major nautical activities, such as swimming, driving various types of boats and jetskis, and consulting friends about problems. Missions have to do with various aspects of the sea; the sequence of missions allows the player to live through an ever-more compelling adventure. For instance, the first mission requires becoming familiar with a jetski drive, the second one places an obstacle in the sea; and eventually the user is invited to compete with other participants. A general ranking indicates the player with the best reputation. The score is a function of two factors: the degree to which the possibilities provided by the game are explored and the effectiveness with which the mission is accomplished.

Besides going on missions, a player is free to explore the virtual world; the sequence of explorations depends on the player's preferences. For instance, as may happen in reality, a jetski close to the beach may attract the attention of a young man, while being ignored by others interested in sailing. The young man can take the jetski and visit the island's beaches or join other players in exploration and competition. Through the chat interface socialization tool, a player can interact with others, challenging them in trials or exchanging comments about missions and tasks. Events and content are also functions of the player because it is the player herself, with his choices and interactions, who

Fig. 2. *SeaGame* snapshots.

Fig. 3. *SeaGame* snapshots.

shapes his own adventure. From this perspective, the presentation of missions by the system is a way of encouraging better exploration of the possibilities offered by the video game.

The elements with which a player typically interacts during missions and explorations include the following:

- *Objects*: jetskis, rubber dinghies, other types of boats, scuba suits, and so on. There are also some noninteractive objects that populate the world so as to make it seem more realistic and to provide security: fish, buoys, regulation signs.
- *Virtual characters*: The island is populated by several conversational virtual humans (CVHs) that have knowledge about specific items. The player can interact with them to get information about the game and aspects related to boating and seamanship.
  The major character types are
  - the *lifeguard*, who is stationed on a trestle in the middle of the beach; he knows about beach safety and nature (e.g., winds and the tide);

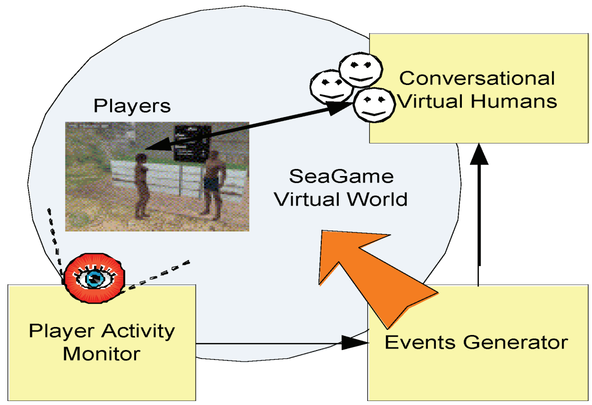


Fig. 4. A high-level view of *SeaGame's* architecture. The players' activity is continuously monitored by the system. Events in the world are generated accordingly. Players can interact with each other and with system-managed conversational virtual humans.

- the *renter* has the boats and jetskis which a player can take to go on adventures; he is an expert on the rules for using the equipment safely;
- the *coast guard* knows the rules and laws related to the sea;
- the *helpbot* is a character that is automatically activated when the player gets lost in the game (e.g., if a player stays in one place for a long time, the bot approaches and explains the possible actions the player can take (e.g., where to rent a rubber boat);
- the *other bots* are role-less characters that populate the island and possess general "first-meeting" knowledge; they can also help the player with location-specific information.

## 4. EDUCATIONAL MODULES

In *SeaGame,* education and learning are embedded and hidden in several mechanisms/modules/situations that are pervasive in the game. They are shown in Figure 4 and described in the following sections. Such features (e.g., a score is assigned as a reward for tasks that conform to criteria for safety at sea) make *SeaGame* an educational game. It is true that as yet we cannot prove how much users learn from *SeaGame*; knowledge acquisition user testing is an ongoing complex task that needs time and resources. But SeaGame has an educational structure and requires knowledge acquisition/testing in order to advance in the game.

### 4.1 Player Activity Monitor

The behavior of the player's avatar is continuously monitored by the system in order to check its compliance with proper safety and fairness rules. The score (which is a great motivator in any game and provides the player with the stimulus for continuous improvement) rewards and penalizes the player. For example, *SeaGame* allows the player to rent a jetski, and then his driving is monitored to verify that the player follows the rules for safe navigation. The score is updated accordingly.

### 4.2 Event Generator

Exploration of the island is animated by events that are initiated by the system. Their sequence is determined at runtime according to the player's monitored performance. The criterion for initiating an event is to spur the player's training in activities best suited to his runtime profile.

Every activity the player's avatar may do in the reconstructed space involves sea-related actions that can be quantitatively evaluated by the system, and hence rewarded by the score.

### 4.3 Conversational Virtual Humans

The player can interact in natural language with conversational virtual humans (CVHs) that provide information and hints about the game mechanics and the surrounding environment (people, objects, and activities, all of which have some educational value). Typically, CVHs embody their area of expert knowledge. For instance, a coast guard knows the safe distance between a motorboat and the coast, and can tell the player about it. The CVHs also have personalities and express emotions related to learning and social interaction aspects. Acquiring knowledge through smart dialog with CVHs is necessary if the player is to increase the levels of his adventure.

### 4.4 Social Interaction

Social interaction among players is supported via geographic proximity criteria. In particular, the system allows players to get in touch with each other through an instant messenger-like user interface (e.g., Skype, Microsoft Live Messenger) if their avatars are close to each other in the VW. This spurs players to perform some collaborative activities, which are rewarded through prizes in scores or with virtual gadgets.

## 5. USER TEST METHODOLOGY

The aim of the user evaluation phase is to understand whether the above-mentioned knowledge components inserted in *SeaGame* are accepted by the users and do not compromise the (usually) highly pleasant and compelling experience of users playing commercial video games. The topic of methodologies for evaluation is gaining increasing relevance for research on the development of video games [Squire 2008]. We contribute to this area by exploring the repertory grid technique and discussing the results.

### 5.1 The Repertory Grid Technique

The most successful feature for a video game, as well as for a serious game, is the player's enjoyment. However, as yet there is no agreement on a model for a standard for player enjoyment [Bernhaupt et al. 2007]. There are several heuristics for designing and evaluating games reported in the literature, which are focused on three main aspects: gameplay, mechanics, and interface [Federoff 2002]. These heuristics are often fragmented and contradictory, as there is no evidence about their relevance with respect to criteria for enjoyment [Sweetser and Wyeth 2005]. From another point of view, many researchers have proposed models based on psychological theories, including disposition theory [Raney 2004]; attitude [Nabi and Krcmar 2004]; transportation theory [Green et al. 2004]; para-social interaction [Nabi and Krcmar 2004]; and flow [Chen 2007; Cowley et al. 2008]. The main drawback of these approaches is that they use tools and measures based on concepts predefined by the researcher (e.g., predefined questionnaires), which may bias the user report [Clarke and Duimering 2006].

For the evaluation tests, we have relied on the repertory grid technique (RGT) methodology [Hassenzahl and Wessler 2000]. Repertory grid is a clinical interviewing technique based on the Personal Constructs Theory (PCT) of personality [Kelly 1955]. It aims at determining an idiosyncratic measure of personality and includes qualitative and quantitative aspects.

The PCT assumes that individuals perceive and evaluate the world (e.g., other individuals, situations, etc.) through similarity-dissimilarity poles, called "personal constructs". The RGT is used to extract an individual's personal construct system that is relevant to a topic—in our case the evaluation of video games.

The RGT's main virtue is that the researcher does not supply users with a predefined set of constructs, which may bias the evaluation process [Bannister and Fransella 1985]. Rather, constructs are defined *a posteriori*, based on an analysis of user comments.

For instance, to understand how a person purchased a movie DVD, he would be asked to freely think of a set of elements (movie DVDs, in this case). Then, the person would be presented with triads of such elements and asked to indicate in what respect two of the three were similar to each other and differed from the third one. These similarity/differentiation factors are recorded as bipolar constructs (i.e., descriptive concepts/properties, such as enjoyable/boring, dynamic/static in the case of movies). Different triads may give rise to similar (or even the same) bipolar properties. The similar properties are then summed together, and the most frequently occurring ones are assigned a higher weight, as they represent the most appropriate properties for characterizing the domain (i.e., the purchase of a movie DVD in our example). All such bipolar constructs (each one with a different weight) are thus shown as the proper dimensions (or classification modes) along which the domain elements are evaluated by the user.

Although this technique was initially developed to understand personality differences in the construction of social perceptions, it has been applied to a wide variety of areas, including evaluation of user experience [Mandryk et al. 2006], and for research on the evaluation of video games [Steed and McDonnell 2003; Boyd et al. 2004]. Based on this analysis and our experience, we believe that RGT facilitates an objective approach to capturing subjective aspects of VG evaluation by allowing an open, broad, and sensitive analysis of several aspects that might have an impact on the user's experience of a video game.

### 5.2 Sampling

We recruited test subjects by contacting teachers at three different high-schools with scientific, technical, and humanities backgrounds. We proposed to each school a one-day workshop on video games and on the educational potential of serious games. We selected a total of 64 students, ranging in age from 16 to 19 (mean 17,4; stadev 0,64). There were 13 females and 51 males; 35 from a technical school, 24 from a scientific one, and 5 from a school with a humanities focus. This sample is clearly biased because we selected students with a strong interest in video games, as we wanted to have opinions from experienced users familiar with state-of-the-art VGs. Indeed, our aim is to understand how state-of-the-art popular and successful games can be enhanced with education-supporting mechanisms without compromising their appeal to their current audience.

With this approach we aim to define an architecture on which to build successful games that support learning. Of course, this architecture, constituted by the educational mechanisms, could be used, and adapted if necessary, in other environments and virtual worlds also, in order to better attract a different audience (e.g., young women, scholars, liberal art students) than current typical gamers.

In a pre-test questionnaire, we tested the users' level of familiarity with video games in order to check the appropriateness of our target group. As expected, participants were quite familiar with VGs (mean 2,56; stddev 1,15 in a 4-grade scale), and would usually spend a huge amount of time playing with consoles and PCs (1 to 3 hours per day).

### 5.3 Evaluation Session

We ran one RGT session at each of the selected schools; the RGT session consisted of the following steps:

1. *Pretest questionnaire*: users were asked to fill a questionnaire that serves to express their experience playing video games.
2. *Element selection*: we asked users to think about their favorite video games and provide a list of VGs of various genres.
3. *Construct elicitation*: we applied the "triad" method. For every meaningful triad (three elements in the VG set defined in step 2), users had to identify how two of the elements are similar but different from the third one. Through this comparison, bipolar constructs (i.e., modes of categorizing the elements) emerged.
4. *Rating video games*: for each elicited construct (i.e., properties/categories defined in step 3), users rated all the selected elements (step 2) on a 5-grade scale.
5. *Playing sessions*: users played *SeaGame* in a session lasting around 30 minutes.
6. *SeaGame evaluation*: users rated *SeaGame* (on the same scale as in step 4) along all the constructs they had elicited in step 3, based on their previous experience with commercial games (i.e., our sample game with the educational

enhancements evaluated according to the properties and categories typical of commercial games).

## 6. DIMENSIONS OF VIDEOGAME EVALUATION

### 6.1 Video Game Dimensions

In the elicitation phase, players use their own criteria to describe the similarities and differences among the elements (video games). Hence the RGT approach yields a large number of different personal bipolar constructs (we have collected a total of 570). Sample bipolar constructs include, "a good experience is necessary to play; it can be played without training"; "the game requires cognitive effort; it can also be played by a monkey".

Unlike clinical studies, we are not interested in identifying idiosyncrasies. Instead, our research aims at finding out the basic and commonly shared criteria that players use in evaluating VGs. To this end, we have analyzed the collected data and grouped the users' personal constructs into clusters—called dimensions—according to a semantic similarity principle. In order to define the clusters, constructs were processed using a discourse- analysis technique.

We obtained 23 basic dimensions. The number of personal constructs grouped under a dimension is an indicator of the relevance of that dimension for the test takers. The higher the number of grouped constructs, the more relevant the cluster, as more test users chose it. The complete list of dimensions follows, with the relevance number in parenthesis: ability-demanding (94), dynamism (58), style (48), engagement (38), emotional affect (35), likelihood (33), sociability (28), enjoyability (28), complexity (24), length of playability (23), technological quality (23), plot (21), physical effort (20), replayability (18), controlability (15), identification (13), open-endedness (12), active involvement (10), competition/cooperation (10), design for a specific target group (4), real-life tasks (3), and evolution (3). The definitions for all the dimensions are provided online.[4]

### 6.2 Comments on the Evaluation of Commercial Video Games

By analyzing the above data, we can gain important insights into factors that players consider key in characterizing their gaming experience.

First, we see that video games are perceived as engaging challenges where personal abilities are continuously put to the test, in particular with emotional involvement and frequent and quick changes in context and situation. This highlights the reactive nature of VGs and stresses the fact that players like being stimulated: showing their reactions in a mechanical—almost unconscious—way, via some informal comments we recorded (e.g., "I play to distract myself," "When I play I don't want to think"). Note that, despite users declaring that they like variety and change, they did not explicitly report the repetitive nature of several of the most popular games (e.g., shoot'em ups and some sport games), which was apparent to the researchers. We could argue that players

[4]www.elios.dibe.unige.it\dimensions.html

like intrinsic repetitive mechanisms and patterns (e.g., shooting, firing, jumping, running) but they want them to be applied in several different contexts and situations and at different levels of difficulty. We could assimilate this to a basic, easy-to-learn alphabet that has to be used in a variety of contexts to tell a variety of tales.

Plot and sociability were not as important; this highlights the fact that users are not particularly interested in these aspects and that the currently most successful VGs do not support them. However, plot and social interaction are important for education [Corbit 2002]; this stresses the relevance of the work that must still be done in game design and game-using education to exploit all the potential of video games and make them useful in supporting knowledge acquisition and skill development. Distinctive style and multimedia quality are relevant evaluation parameters, which stresses the importance of design and technological excellence.

The dimensions we elicited from user tests include the heuristics normally used by professionals and players when writing game reviews in specialized magazines and Web sites (e.g., Game Spot[5]), that are focused on the game interface and mechanics [Larsen 2008]. Other heuristics are mentioned in academic work, such as the well known GameFlow approach [Chen 2007; Cowley et al. 2008]; they underline the importance of involving the player in a game through immersion and concentration.

Our dimension list includes the heuristics of both the above-mentioned typologies, and has two important features: (1) it gives a weight to the relevance of the various dimensions and (2) is based on the experience of real users rather than on psychological theories or on the practice and knowledge of professional users and reviewers.

### 6.3 SeaGame Evaluation

Once the dimensions have been elicited, it is important to see how *SeaGame* is assessed by the same players along parameters that are exclusively based on the players' experience with commercially successful games. This should give an objective evaluation as to whether (and how) the learning mechanisms embedded in an educational game have a (negative) impact on the overall entertainment (here we assume that entertainment is the driving factor for playing state-of the-art VGs).

Figure 5 shows the average scores of commercial video games and *SeaGame* along all the elicited dimensions (we dropped dimensions with a relevance value below 5).

Roughly speaking, the data show that *SeaGame* is generally perceived as similar to state-of-the-art video games, which suggests that its educational mechanisms are integrated quite well in a meaningful and entertaining way.

In order to compare the data quantitatively, we performed a paired-samples t-test analysis, whose results are shown in Figure 5. *SeaGame* is seen as being similar to commercial VGs along several dimensions (e.g., enjoyability, technological quality, style, complexity, controllability, playability length, plot,

[5]www.gamespot.com

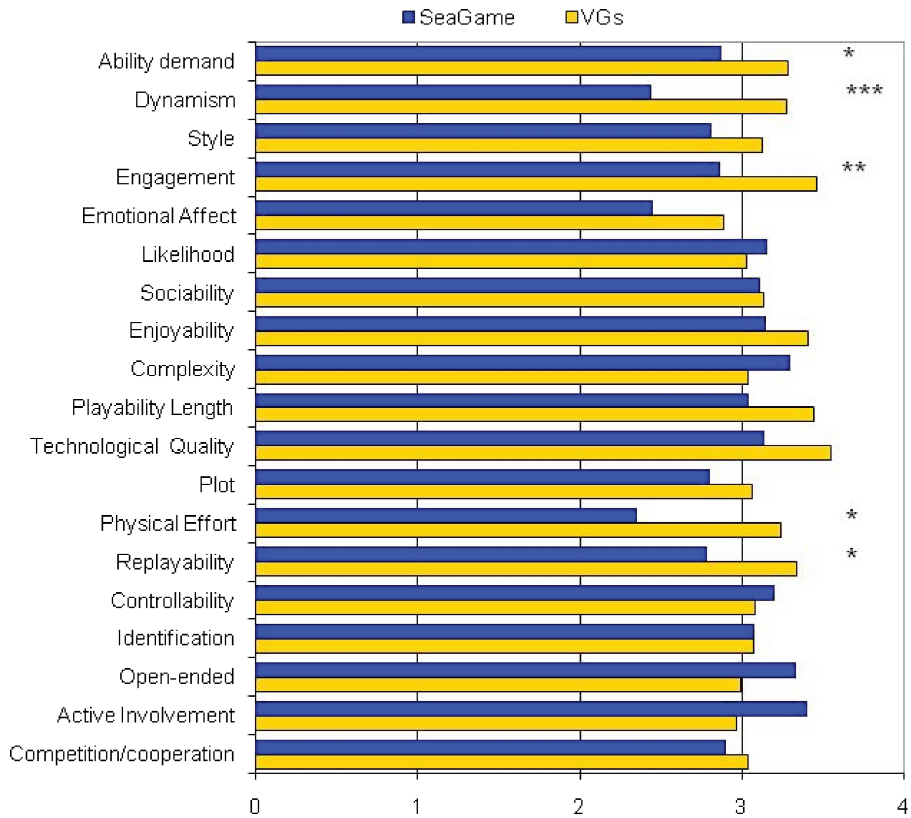


Fig. 5. Comparing commercial VGs and *Seagame* along the elicited dimensions. Stars indicate dimensions for which differences are statistically significant according to a paired-samples t-test analysis (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$).

identification, competition, active evolvement, verisimilitude, open-ended, and sociability). But there are statistically relevant differences in five important dimensions, which are marked with asterisks in Figure 5.

The most apparent difference is in respect to dynamism. Users perceive commercial video games as being more varied and with more surprising events than *SeaGame*. We speculate that *SeaGame's* lack in dynamism is also related to less significant differences in other dimensions, such as replayability, engagement, ability demand, and physical effort. We also argue that the differences are not only due to *SeaGame's* learning mechanisms, but also to the very high quality of the commercial video games to which *SeaGame* is compared.

### 6.4 Architectural Improvement

Test results showed two major directions for possible improvements.

The first concerns content. In particular, we believe that we should increase the number of items and events and situations (more ships, areas with organized events like races), add conversational virtual humans (CVHs) with new and intriguing roles (e.g., a fisherman, a scuba diver), and augment the CVHs' depth of knowledge so as to provide more compelling dialog. This should make the environment richer and more challenging to explore.

The second improvement concerns architecture, and involves the introduction of new mechanisms to be integrated into the environment to increase the game's dynamism and address the demand for stimulation. Hence we decided to test the use of microGames (mGs) [Bellotti et al. 2008]. mGs are simple, short games that focus the player's attention on a particular item that he may find during exploration of the 3D world. Typically, mGs are taken from well-known game models such as *Puzzle, MemoryGame, FindTheWrongDetails, PutItInItsRightPlace*. The idea is that they can be played immediately, so that the player can focus on their content rather than on learning how to play them. We can divide the mG typologies into three broad categories according to the cognitive ability the typology most calls for: observation games (e.g., find details), reflection games (e.g., apply rules/knowledge), and action/arcade mGs (where quick reflexes are required and stimulated). The mGs are typically added as bonus events (e.g., when the player performs particularly well at a given task), as tests to pass a level, or can be found and accessed by the player as landmarks during exploration.

MGs are software templates that can be instantiated with a variety of content and placed in different situations. Thus, the concept of mGs, like the other educational mechanisms we presented before, is general and independent of *SeaGame*, and can be applied to other instances of educational games.

### 6.5 Evaluating the Impact of MGs

In order to assess the validity of the improvement, we developed a new version of *SeaGame* that features four mGs templates: *Puzzle, FindTheWrongDetails, RightPlace,* and *CatchIt,* a 2D arcade game. We created instances of such models for the major beaches of *SeaGame*, providing content—for instance—about the names of winds and their direction, emergency phone numbers, and procedures and equipment for scuba diving. We then performed another session of user tests, organized as a one-day workshop in our lab, with ten test takers with similar features to the previous ones (in particular, they all had experience with video games). Like the initial test takers, this was the first time the second takers played with *SeaGame*. We did not show them the previous version of the game, so that the test takers were not able to compare the two. We were interested in understanding whether the upgraded *SeaGame* was perceived as being similar to state-of-the-art commercial games. Before the *SeaGame* trial, we asked gamers to rate their favorite commercial VGs along nine dimensions on a 5-grade scale. In the first test, there were five dimensions on which *SeaGame* was considered significantly worse than commercial VGs; we added another four relevant dimensions as a control. After the trial, we asked the test takers to rate *SeaGame* along the same nine dimensions. Results reported in Table I show that the differences are less than in the first tests, and none of them are statistically significant according to a paired-samples t-test. Ratings along control dimensions also confirm the absence of statistical differences for these dimensions.

Table I. Comparing Commercial Video Games to the Upgraded *SeaGame* (The first five rows represent the dimensions along which the previous version of the SG was significantly worse than commercial VGs; P values refer to a paired-sample t-test; no value is statistically significant).

| Dimensions | VGs Mean (standard deviation) | SG with mGs Mean (standard deviation) | P value |
|---|---|---|---|
| Ability-demand | 3.27 (1.53) | 3.33 (1.22) | 0.93 |
| Dynamism | 2.82 (1.15) | 2.56 (0.88) | 0.29 |
| Engagement | 2.95 (1.00) | 3.11 (0.78) | 0.80 |
| Emotional affect | 2.88 (1.13) | 2.00 (1.00) | 0.05 |
| Realism | 3.05 (1.77) | 3.11 (2.03) | 0.98 |
| Sociability | 2.89 (1.62) | 3.11 (1.54) | 0.75 |
| Plot | 2.69 (1.05) | 1.89 (1.17) | 0.13 |
| Physical effort | 3.00 (1.51) | 2.33 (1.66) | 0.10 |
| Replayability | 3.33 (1.41) | 2.22 (1.48) | 0.06 |

Observing user interaction with the improved version of the game, we noticed that the players were immediately and continuously involved in the game, which was due to the richness of the 3D world, in which the player was faced with a compelling game that required him to perform two major types of behaviors: (1) to focus on recognizing items, understand their meanings and react promptly; and (2) to think of rules/data/inferences based on previous knowledge and experience (also gained from *SeaGame* itself).

In all cases, the mGs were the hook to make the player think of or get more information for items representing the knowledge embedded in *SeaGame*.

## 7. CONCLUSIONS AND FUTURE WORK

Video games are usually perceived and appreciated as highly dynamic personal challenges. Thus they can be key tools to stimulate and enhance user attention and involvement in useful tasks. In online games, users play by competing and cooperating to advance their names on the scoreboard. This aspect of competition/collaboration with peers encourages players to explore all the game's features and perform well at the related tasks so as to increase their scores and advance in the game levels. Such a powerful incentive in any good game would, if effectively applied to educational games, have the key effect of exposing players to a growing learning content embedded in various game activities, thus motivating them to acquire further knowledge and continuously improve skills. Despite this potential, commercial games seldom provide specific educational value.

Hence we saw the need for compartmentalizing components of a game engine in a way that makes it easier and more efficient to integrate the graphics interface (already addressed in state-of-the-art successful video games) and the educational aspect, which is poor in successful video games. Hence we have defined a general set of mechanisms and modules (e.g., CVHs, mGs) that can be inserted in state-of-the-art video game environments and are aimed at promoting various kinds of knowledge and procedural skill acquisition.

In order to investigate and validate our approach, we built an educational game, called *SeaGame*, taking a state-of-the-art commercial game-development approach, and enriched the environment with instances of already developed educational modules; *SeaGame* is an example of this approach. The proposed mechanisms and modules lend themselves well to application in the context of sandbox games, where the player is encouraged to freely explore the knowledge contained in the virtual world. However, these mechanisms and modules can also be used in more story-driven games, as they provide generic means to embed knowledge acquisition and test activities which can be inserted at relevant points in the story.

By analyzing user test results, we see that *SeaGame* is perceived as being quite similar to commercial video games, which argues that the proposed mechanisms do not compromise the overall enjoyability of the game. Reaching a statistical similarity with successful commercial video games along several dimensions shows that it is possible to support learning through an entertaining experience, which is key to attracting a wide demographic that is currently not involved in educational activities during leisure time. It is important to stress three points: (1) we made a comparison to high-quality commercial video games (which typically involve huge development budgets); (2) the evaluation concerned dimensions elicited from the players' experience with successful commercial VGs only; (3) test takers were very familiar with the world of commercial VGs, and thus were experts on the mechanisms of such successful games.

The results of this research are general, since they take the standards of commercial games into account, and the proposed educational enhancements are independent of the content and can be instantiated in a variety of educational contexts. Such results open interesting perspectives and research questions on the effective use of the proposed enhancement mechanisms and modules. Sample items include the scheduling rules and principles for events; user profiling to enhance learning; the number, length, and variety of items and situations in the virtual world; the type, contents, and modalities in the appearance of mGs; the CVHs' depth of knowledge and the specialization of CVHs' roles; the modalities of providing feedback to the user; and the type of reconstructed settings (detailed/realistic vs. symbolic/abstract).

## REFERENCES

BANNISTER, D. AND FRANSELLA, F. 1985. *Inquiring Man*. 3rd (ed.), Routledge, London.

BELLOTTI, F., BERTA, R., DE GLORIA, A., AND ZAPPI, V. 2008. Exploring gaming mechanisms to enhance knowledge acquisition in virtual worlds. In *Proceedings of the Third International Conference on Digital Interactive Media in Entertainment and Arts* (DIMEA).

BELLOTTI, F., BERTA, R., PELLEGRINO, M., PRIMAVERA, L., AND DE GLORIA, A. 2007. Learning contents by videogame tricks. In *Proceedings of the Learning with Games Conference*, 24–26.

BERNHAUPT, R., ECKSCHLAGER, M., AND TSCHELIGI, M. 2007. Methods for evaluating games: How to measure usability and user experience in games? In *Proceedings of the International Conference on Advances in Computer Entertainment Technology*.

BOYD, S., CARINI, D., AND CARINI, C. 2004. Constructing a player-centered definition of fun for video games design. In *Proceedings of the HCI*, 117–132, 6–10.

CARLESS, S. 2005. Informa predicts $58.4B game industry in 2007. Gamasutra. www.gamasutra.com/php-bin/news_index.php?story=6942.

CARTELLI, A. 2006. *Teaching in the Knowledge Society: New Skills And Instruments for Teachers*. Idea Group Inc.

CHEN, J. 2007. Flow in games (and everything else). *Commun. ACM 50*, 4, 31–34.

CLARKE, D. AND DUIMERING, P. R. 2006. How computer gamers experience the game situation: A behavioral study. *ACM Computers Entertainment 4*, 3.

CORBIT, M. 2002. Building virtual worlds for informal science learning (SciCentr and SciFair). *Active Worlds Educational Universe 11*, 1, 55–67.

COWLEY, B., CHARLES, D., BLACK, M., AND HICKEY, R. 2008. Toward an understanding of flow in video games. *ACM Computers Entertainment 6*, 2, 1–27.

DICKEY, M. D. 2003. Teaching in 3D: Pedagogical affordances and constraints of 3D virtual worlds for synchronous distance learning. *Distance Education 24*, 1, 105–121.

DUCHENEAUT, N., YEE, N., NICKELL, E., AND MOORE. R. J. 2006. Games and performances: "Alone together?": Exploring the social dynamics of massively multiplayer online games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '06). ACM Press, New York.

FEDEROFF, M. 2002. Heuristics and usability guidelines for the creation and evaluation of fun in video games. Unpublished thesis, Indiana University, Bloomington. http://www.melissafederoff.com/thesis.html.

FULLERTON, T., SWAIN, C., AND HOFFMAN, S. 2004. *Game Design Workshop. Designing, Prototyping and Playtesting Games*. CMP Books, San Francisco, CA.

GREEN, M., BROCK, T., AND KAUFMAN, G. 2004. Understanding media enjoyment: The role of transportation into narrative worlds. *Communication Theory 14*, 4, 311–327.

HASSENZAHL, M. AND WESSLER, R. 2000. Capturing design space from a user perspective: The repertory grid technique revisited. *Int. J. Human Computer Interaction 12*, 3/4, 441–459.

HUGHES, C., MOSHELL, E., AND MARCH, J. 1997. Shared virtual worlds for experiment. *ACM Multimedia 5*, 2, 145–154.

KELLY, G. 1955. *The Psychology of Personal Constructs*. Vols.1/2. Routledge, London.

LARSEN, J. M. 2008. Evaluating user experience – How game reviewers do it. *CHI 2008 Conference Workshop on Evaluating User Experiences in Games.*

LIVINGSTONE, D. AND KEMP, J. 2006. Massively multi-learner: recent advances in 3D social environments, computing and information systems. *J. School Computing 10*, 2.

LOSH, E. 2005. In country with tactical Iraqi: Trust, identity, and language learning in a military video game digital experience. In *Proceedings of the Digital Arts and Culture Conference*, 69–78.

MANDRYK, R. L., ATKINS, M. S., AND INKPEN, K. M. 2006. A continuous and objective evaluation of emotional experience with interactive play environments. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.

MAYO, M. J. 2007. Games for science and engineering education. *Commun. ACM 50*, 7 (July), 30–35.

MICHAEL, D. AND CHEN, S. 2006. Serious games: Games that educate, train, and inform. In *Thompson Course in Technology*, *PTR.*

NABI, R. AND KRCMAR, M. 2004. Conceptualizing media enjoyment as attitude: Implications for mass media effects research. *Communication Theory 4*, 14 288–310.

OLNEY, A. M. 2007. Dialogue generation for robotic portraits. In *Proceedings of the International Joint Conference on Artificial Intelligence 5th Workshop on Knowledge and Reasoning in Practical Dialogue Systems*, 15–21.

PILLAY, H., BROWNLEE, J.. AND WILSS, L. 1999. Cognition and recreational computer games: Implications for educational technology. *J. Research Computing Education 32*, 1, 203–215.

PRENSKY, M. 2003. Digital game-based learning. *ACM Computers Entertainment 1*, 1, 21.

RANEY, A. 2004. Expanding disposition theory: Reconsidering character liking, moral evaluations, and enjoyment. *Communication Theory,* 348–369.

RAYBOURN, E. M., DEAGLE, E., MENDINA, K., AND HENEGHAN, J. 2005. Adaptive thinking and leadership simulation game training for special forces officers. In *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference.*

RIEBER, P. 1996. Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations, and games. *Educational Technology Research Development 44*, 2, 43–58.

RITZEMA, T. AND HARRIS, B. 2008. The use of second life for distance education, *J. Computing Sciences Colleges 23*, 6, 110–116.

ROVAI, A. P. 2002. Building sense of community at a distance. *Int. Rev. Research Open Distance Learning*. http://www.irrodl.org/index.php/irrodl/article/ view/79/152.

SLINEY, A. AND MURPHY, D. 2008. JDoc: A serious game for medical learning, achi. In *Proceedings of the First International Conference on Advances in Computer-Human Interaction*, 131–136.

SQUIRE, K. 2008. Open-ended video games: A model for developing learning for the interactive age. In *The Ecology of Games: Connecting Youth, Games, and Learning*, K. Salen (ed.), MIT Press, Cambridge, MA, 167–198. doi: 10.1162/dmal.9780262693646.167.

STEED, A. AND MCDONNELL, J. 2003. Experiences with repertory grid analysis for investigating effectiveness of virtual environments. *PRESENCE,* Aalborg University.

SWEETSER, P. AND WYETH, P. 2005. GameFlow: A model for evaluating player enjoyment in games. *ACM Computers Entertainment 3*, 3.

WALLACE, R. 2003. The elements of AIML style. ALICE AI Foundation.

ZYDA, M. 2005. From visual simulation to virtual reality to games. *IEEE Computer*, 25–32.

ZYDA, M. 2007. Special issue on serious games, *Commun. ACM 50*, 7.

Received November 2008; revised February 2009; accepted February 2009