LEARN X DESIGN 2021
Engaging with Challenges in Design Education
6th International Conference for Design Education Researchers
Shandong University of Art & Design | Jinan, China

# Designing Criteria for Developing Educational Multimedia Games

Chaitanya Solanki and Deepak John Mathew
https://doi.org/10.21606/drs_lxd2021.09. 282

Increasing research is being done into the relationship between learning and games in recent years. Player engagement and intrinsic/extrinsic motivation have shown to be pertinent in improving the quality of knowledge retention in game-based learning environments. Similarly, the use of multimedia in game-based learning environments has also shown to have significant potential for effective learning; however, it is unclear whether a generalized criterion can be designed for it. This work presents a review of theories and guidelines that pertain to learning environments, game design, and multimedia learning, in an effort to distil the key elements which can help develop design criteria that can contribute to efficient educational multimedia game development.

Keywords: learning environments; design education; educational games; multimedia learning

## Introduction

One of the overall goals of educational game design is to develop game-based applications that can be compared to the contemporary classroom teaching-learning methods in their efficacy, engagement, and acceptability. In a venture to design these interactions and activities, it is necessary to recognize what constitutes good design and development, in terms of engagement, usability, and educational effectiveness. This paper presents two sets of criteria that could help support the design and development of computer games for the purpose of education. A review of the existing guidelines in the areas of game design, learning environments, and multimedia learning was done to understand the factors that can influence educational game design. In the end, the review was used to put together two sets of criteria for the effective development of educational games, where one focused on the educational design of the game while the other focused on the multimedia use and design. The following section studies the guidelines that are descriptive for designing appropriate learning environments, game designs, and multimedia learning.

## Guidelines for Designing Learning Environments

In a paper that tries to theorize *Rich Environments for Active Learning*, Grabinger & Dunlap (1995) review the works of Hannafin (1992) and Collins (1995) and define learning environments to have the following qualities (Grabinger & Dunlap, 1995; Hannafin, 1992; Collins, 1995):

- Learning environments resonate with constructivist concepts and theories
- They are able to encourage the learner to study and investigate within authentic contexts
- Trains qualities in the learner for responsibility, making decisions, taking initiative and curios learning
- Encourages collaboration through an atmosphere of building knowledge and mutual learning
- Is dynamic and interdisciplinary in transmitting knowledge and has activities that can help the learner merge old knowledge with newly learned information, consequently helping them in building mental models and concepts

McLoughlin and Oliver (2000) in their pursuit to develop an online unit for the indigenous learners of Australia, highlight ten guiding principles for flexible and responsive learning environments (McLoughlin and Oliver, 2000)

while Rieber (2001) emphasizes in their research that serious play needs to be a fundamental goal for developing learning environments and describes these environments as space where time, resources, and reasons are available to encourage the learning of a specific set of information (Rieber, 2001). When trying to understand why it was difficult for participants to understand scientific concepts and how the construction of learning environments could help rectify this problem, Vosniadou and team (2001) described four principles that might affect the development of a successful learning environment (Vosniadou et al., 2001). The principles suggested in these publications have been brought together and distilled into the following pointers below:

### Flexibility Towards the Needs and Preferences of the Learner

The tasks included in learning environments should be flexible enough to accommodate the preferences, learning styles, and speed of various participants. The tasks could range from the goals that transmit learning as well as the simple navigation and understanding of the new environment itself. Even the mode of instruction should be inclusive of the varying learning capabilities of different participants. In the context of serious games, De Freitas & Jarvis (2006) highlight the need for understanding the learner preferences through demographics, preferences, groups, and skills.

### Social Communication

This alludes to the presence of channels that allow the learner and the teacher to interact with each other. These channels are encouraged to be free highways of information, independent from any technical or performative complication. Social communication also includes participant-to-participant interaction which, if not intentionally difficult to achieve, should be easily accessible to the users. A literature review by Kangas et al. (2017) regarding educational games in the classroom, emphasized that the teacher's communication activities helped the learner/player understand the goal better. The teacher's role was described as a scaffold that can help the students during gameplay and support learning.

### Progression by User Actions

The learning and the environment that provides for it should excite the learners by having action-based results. This ensures that the participants feel that their actions will affect their environment and thus navigate and interact accordingly. To take an example, in contrast to a textbook, where no action can be taken to interact with the content, a web page can provide for a much more versatile learning experience where multimedia and information navigation could very well be dictated by the user. To achieve progression through user actions in the context of games, Juul (2002) suggests giving the user some freedom to explore an environment where interesting actions and reactions take place only in one direction. This can encourage the user to direct themselves at meaningful interactions, which will consequently progress the game to completion.

### Varied Resources of Information

The learning environments should include multiple resources of information that can help impart teachings from different perspectives. A simple example could be to use both animations as well as a physical 3D model to explain the workings of a human heart; here one resource of information describes the kinetic nature of the heart's performance whereas the other can help understand its physiology in life-size. Similarly, some concepts in the learning environments could benefit the learner if they can have multiple perspectives of the same information. An example from the research done by Schrier (2006) in their augmented reality game *Reliving the Revolution*, the participants had to construct their way through the game environment. The author observed that though the abundance of information and information mediums were at first overwhelming for the participants, it later helped them in orienting themselves and encouraged them to develop geographical and intellectual routes throughout the game.

Collins and team (2000) in their paper wrote about the role of different media in the design of learning environments describing the distinct characteristics that varying mediums have to offer in terms of recording, production, transmission, and social interactions. They highlight the constraints of using the most effective mediums for learning environments as there is observed to be a tendency to shift back to familiar forms of teaching-learning. Collins, et al. (2000) also observe that producing digital media can be expensive and timeconsuming but emphasize that the appropriate selection of a medium can be exponentially beneficial to the learner as in most cases, one medium can transmit certain information much better than another; to take an example of how an animation would be greatly more efficient for teaching biology than using images, even though textbooks tend to revert to the use images in most cases (Collins, et al., 2000). The use of different media to effectively convey information highlights the need to understand the role of multimedia in learning.

## Guidelines for Multimedia Usage in Learning

In addition to the guidelines that direct the development of learning environments in the preceding subsection, a review of the potential of multimedia usage in the field of learning is performed in this subsection. When considering the learning from technological interfaces, it is key to consider the range of informational channels that exist. Audio, graphics, animation, images, video, augmented reality, virtual reality and haptic feedback are all possibilities that can be built into digital learning. The support of multimedia usage in learning is first examined in this subsection through the review of a few theories that define and support multimedia learning, following which a review is conducted of the available guidelines that present factors which could improve learning outcomes.

## Multimedia & Learning

The premise being that learners can understand concepts better through multiple mediums of information (like images and text) when compared to a single medium of presentation (only text or images), Mayer (2002) defines multimedia learning as a system in which there exist multiple modes of information delivery. This 3 information can be delivered to the varying sensory modalities of the user through a diverse set of equipment. Mayer (2002) summarizes multimedia learning as an information acquisition process or the process of knowledge construction in which multiple mediums of information contribute to the delivery of information. This is an extension of the dual coding theory by Paivio (1990) where it was hypothesized that there exist two cognitive subsystems for the user, one which deals with verbal information, while the other specializes in dealing with non-verbal information. Mayer (2001) displays supportive research that combines the use of text and visual images resulting in better learning when compared to the text alone and also that the effectiveness of learning is increased when the text is physically closer to the images, making way for better correlation. The research also supports the theories that in multimedia learning, unrelated information is better-left excluded and that the narration along with animation is far more effective than animation with text only.

In the study done by Schnotz & Bannert (2003), they randomly assigned sixty students to one out of three groups where they were presented with similar information but in varied visual formats. One group was presented with only textual information, while the other two groups were given different images along with the text. The goal of the research was to analyze how the structure of graphics can affect the learning capabilities of the students. The results indicated that the structure of the graphics affected the structure of the mental models of the students. Some questions were better solved by the students of the first group with graphical representations, while certain questions were solved better by the other group with graphical representations. There were also some questions that were better solved by the only text group. The results indicated that appropriate graphical representations (in relation to the task questions) were beneficial to the construction of mental models for learners. It also found that though task-appropriate graphics encouraged meaningful learning, task-inappropriate graphics could instead hinder the efficiency of learning for the participants.

In the research by Plass, et al. (1998), the effectiveness of providing visual information along with text was tested on English-speaking college students who had enrolled in a German course. In a test where they had to read a German story, the students were given an option to either see the translation of some of the keywords in the story(textual annotation) or they could view an image/video clip that represented the word(visual annotation) The results, consistent with the generative theory of multimedia, showed that the students who had opted to view the textual as well the visual annotation performed better than the students who had opted just the textual translation.

### Cognitive Theory of Multimedia Learning (CTML)

Multimedia learning observes that learners can meaningfully acquire information better from multiple mediums of information reception than only one. For example, learning the same information from images and text might help the learner retain the content better when compared to just plain text, this is referred to as the multimedia principle (Mayer, 2005). It is asserted that multimedia learning occurs when the learners is able to mentally develop cognitive representations of concepts through the help of correlation between more than one medium of information. Here the textual nature of words can range from audio narration to the written text on an interface, and the reference to pictures can range from graphical imagery, illustrations, videographic content, and/or animated representations. This observation is consistent with the generative theory of multimedia learning that suggests that the participants mentally pick out appropriate verbal and visual information, assort them and then organize the information into cohesive and cogent mental models of representation that they then integrate with existing information in their cognition (Mayer, R. E. & Moreno, R., 1998). Sorden (2012)

draws the key points from the theories of multimedia learning and distills them into the 'cognitive theory of multimedia learning' by mainly examining the works of Paivio (1990), Baddeley (1986), Mayer (2002), and Sweller (2005). The main takeaways from these works are as follows:

- Cognition is bifurcated into a dual-channel subsystem containing a visual and an auditory channel
- Sensory, working, and long-term are the three key memory stores
- The magnitude of cognitive processing in the working memory is limited
- The selection of words and images, the assortment of words and images, and the integration of new knowledge with old knowledge are described as the 5 key processes of cognition when performing selection, organization, and/or integration.

**Application of CTML** - After understanding some of the viewpoints that help describe multimedia learning and the cognitive theory behind it, the key aspects of the application of CTML (Cognitive Theory of Multimedia Learning) are highlighted by Sorden (2012) in their paper under five points. The first point is the use of a learner-centered approach where the medium of instruction and learning, rather than being technology-centered, takes into account the comforts and cognitive range of the learner. The second point highlights the importance of taking into consideration the cognitive load that the instructional medium will entrust upon the user and how it can be managed safely and efficiently. Exercises that contribute to a reduction in cognitive load and an increase in the learner's interest are shown to be two efficient learning strategies by Mayer et al.,(2004) in their research. The third important aspect highlighted by Sorden (2012) pertains to the proper analysis of a task; in this scenario, a task refers to an exercise or an activity that a learner will face when trying to understand a concept. If the task being designed is outside the learner's range of abilities, it can cause unnecessary frustrations for the user, which might even make the learner drop the activity altogether. It is suggested that the task analysis should be done to evaluate the content being transmitted towards the learner, understand the range of the learner's ability, and breakdown the educational objectives that the task needs to achieve. The fourth point concerns the guided instructions that are given to the learner. According to CTML, solved examples and guided instructions are better for familiarizing the learner with the activity than when compared to discovery learning by the learners themselves. The last point is interactivity, which is in itself a large area of research, but here it pertains to the emergence of interest in learning when attention is paid to interactive things like learner control, feedback, and guidance into the lesson. The interaction is suggested to be constructive, which positively informs the learner about the workings of the new environment while letting them freely control their abilities to perform the task fluently (Sorden, 2012). The positive acceptance of multimedia learning is reflected in many studies, including the survey in which Pastore (2016) shows that the scores of the multimedia preference groups were higher than the groups that preferred single media.

**Evaluation of CTML** - Sorden (2012) observes that it is difficult to ascertain any single method of evaluating CTML research. According to Mayer (2009), a key approach in CTML's evaluation could be by quantitatively experimenting and drawing comparisons, where randomized and experimental control could try and determine which of the instructional method is more appropriate for learning. Retention of information and the honest transfer data could be considered attributes that validate learning (Sorden, 2012; Mayer, 2009).

## Pedagogical Praxis

Shaffer (2004) in their paper Pedagogical Praxis: The Professions as Models for Postindustrial Education outlines a general theory of how under the right conditions, the use of digital information technologies to create various professional learning environments can be helpful for the participants to learn and transition themselves into contributing professionals of their own communities. The basis of this theory is to use technology to build a digital bridge that imitates, but bypasses conventional learning and lets the users adopt information about certain professions through recreated learning environments of those respective professions. Finally, the results can be measured by a comparative analysis between the learners generated through conventional teaching methods versus the learners informed through the developed technological aide. The theory is described in five steps which are as follows: (1) To conduct a baseline study of how conventional training methods are given to future professionals and understand how the learners relate to the respective professional ways of ideation and execution (2) To conduct ethnographic studies that can inform the researcher better about the training practices of future professionals (3) After a careful analysis of the ethnographic practice, to develop or adapt existing technologies that can recreate the general mechanisms of the profession and still be within the operative reach of the learner (4) To build a learning environment that contains the technology built/adapted and apply it to the learners using the heuristics found in the ethnographic studies earlier (5) To finally examine the outcomes by comparing the learning with the domain of

the respective profession, and by documenting how the learning contextualizes itself with respect to the professional practice (Shaffer, 2004).

Although, Shaffer (2004) does not specifically mention the use of multimedia, their suggestion to adopt appropriate technology or set of technologies that can suit the learning of a particular profession axiomatically indicate the use of multiple mediums. In a concluding study, Shaffer (2004) tests this theory by applying it to the domains of architecture, mediation, and journalism. The results indicated that pedagogical praxis could be employed to teach other professional domains (and consequently subjects such as biology, mathematics, ethics, etc.) and that this methodology was applicable to learners from varying socioeconomic backgrounds (Shaffer, 2004).

It has majorly been accepted that the appropriate application of multimedia teaching can contribute to increased learning. The work by Mayer, Shaffer, and others has been largely appreciated, and though there holds some criticism as to whether this approach is effective, most of the supportive research for multimedia learning is evidence-based with publications in significant journals. The key findings from the above researches which guide the development of an effective multimedia learning activity have been summarized as points in the following:

**Technology Selection** - The selection of the set of technologies that build the multimedia experience should complement the teaching content as well as the learner's range of abilities. For example, when considering the content, the use of audio narration and pronunciation will be better for learning a spoken foreign language than when compared to learning a written foreign language. Similarly, when taking into consideration the range of abilities of the user, the use of bright vivid colours in the visual representations would be better suited for teaching young learners than the use of subtle shades and hues. The technology selection, which was denoted as delivery methods of information in the study by Buch & Bartley (2002) reinforced that all participants had diverging learning styles and preferences, where one group preferred learning through traditional methods of information delivery while the others preferred various novel technologies.

**Task Analysis** - The design of the multimedia experience should involve a clear analysis of the task that would require the participants to do or absorb. If the task turns out to be difficult for the learners, or if the task is unable to achieve the educational objectives that it was intended to, then the use of multimedia might have negative effects. To take an example, the use of drawing activities to teach history to a class might or might not be the most efficient method when compared to showing images and videos of historical events. The effectiveness of the task and the activity will greatly depend on the educational objectives that the teaching is trying to achieve. Practical methodologies like the Cognitive Task Analysis (CTA) technique, could be applied in understanding and dissecting the task at hand (Schraagen et al., 2000).

**Content Representation** - Some of the research showcased how the appropriate representation of content was key to the increase in meaningful and applicable learning. In an exercise where the students asked to answer various questions about the circumnavigation of the world, some questions were answered better by students who had a circular representation of the world's geography while certain questions were better answered by students who were given a flat, carpet-like representation of the globe (Schnotz & Bannert, 2003). This testifies to the theory that every piece of information will have a certain way of representation that can help the learners understand it better and meaningfully retain the contents. The previous step of task analysis can aid in the understanding and selection of an appropriate medium and format to represent the content.

**Interactivity** - The interactivity of the experience will need to complement what the teaching is trying to achieve, however, it has been found that an easy introduction to the exercise, along with giving the learner's some freedom to explore the new environment has had positive effects on the learning experience. The design of interaction will need to encourage the emergence of interest in learning for the user. The demonstration of some solved activities along with some guided instruction could help learners get a better understanding of the interaction. Kim et al. (2019) in an effort to develop a pedagogical framework called the game-based structural debriefing (GBSD) also emphasize the initial use of a simpler introduction for multimedia interactions.

Through the above reviews of works, it can be positively induced that the use of multimedia, if applied appropriately, can result in an increased interest of the learner, consequently resulting in better and meaningful learning. Some research has also indicated that the activity being performed by the learner, needs to constructively engage the participant in order to impart learning. Educational games are learning environments that make use of multimedia in an effort to impart knowledge. The following section reviews some of the guidelines that theorize how games can be better designed in order to enhance learning.

## Guidelines for Game Design Intended for Learning

The following subsection will first review some of the theories of educational game design, after which a review

is done for understanding some of the guiding principles that emerge from these theories. It is also important to examine the use of learning theories that are employed to develop educational games or game assisted learning. The theories examined under this subsection range from the earlier learning concepts like behaviorism and cognitivism, to the relatively recent learning concepts like situated learning theory and distributed authentic professionalism.

### Behaviorism

Generally attributed to Thorndike (1913) and Pavlov (1927), behaviorism subscribes to the thinking that learning can be generated and incorporated through stimulation and reinforcement. The theory bases itself upon the assumptions that firstly, a change in behavior can be described as learning, secondly that the environment of the individual greatly influences behavior and consequently learning, and finally that the application and process of stimulation and reinforcement are pertinent to the process of learning (Grippin & Peters, 1983; Thorndike,1913; Pavlov, 1927; Watson, 1997).

### Cognitivism

Unlike behaviorism, cognitivism pertains to the assumptions that firstly, the memory is responsible for the assessment, organization, and processing of information, and secondly, that the existing prior knowledge is one of the most important factors in learning. The learner is portrayed as a processor of information, where the mind is basically responsible for all learning and should be examined thoroughly (Merriam & Baumgartner, 2020).

### Humanism

The theory of humanism treats individuals as vessels with values and intentions. The theory differentiates itself from behaviorism and cognitivism as it does not subscribe to learning being defined by the construction of meaning, or that the recurring stimuli and reinforcement could provide for definitive learning. Experiential learning is endorsed by humanism, as it defines its goals to enable every individual to be self-actualized and cooperative. The theory suggests tailored learning which is learner-centered, where the educator facilitates every problem or difficulty that the learner might individually encounter (Combs, 1981; Kolb, 1984; Huitt, 2001)

### Constructivism

Considering learning as a continuous constructive process, constructivism portrays the learner as an entity with the capability of constructing information and consequently learning. The theory assumes that learners continuously create and build their own subjective mental models of objective reality, and by linking newer information with their existing knowledge base, individuals can keep updating their personal mental representations (Brown, Collins, & Duguid, 1989; Bednar, Cunningham, Duffy, & Perry, 1992).

In a systematic literature review by Wu et al. (2012) which used a meta-analysis approach, it was found that most of the studies pertaining to game-assisted learning did not focus on foundations of learning theories. However, the studies that did highlight the use of learning theories revealed that, in recent times, humanism and constructivism were more popular in game-assisted learning when compared to behaviorism or cognitivism, even more for experiential learning. One of the reasons that were highlighted for humanism and constructivism theories to be more popular in recent times was due to the increasing adoption of learnercentered approaches when compared to teacher-centered approaches (Wu et al., 2012).

### Situated Learning Theory

Defined by Lave and Wenger (1991), situated learning subscribes to the notion that learning is deeply influenced by the particular physical or cultural environment that it takes place in. Here, learning becomes an active engagement process of the participant with their environment through tasks. The activities that redirect the participant to interact with the immediate setting contextualized learning for the user where they gradually learn and master the inner workings of that environment. Situated learning encourages research to analyze the relationship between the component units such as the participants, the environment, the activities and discourages the analysis of units as single identities (Lave & Wenger, 1991). Gee (2009) mirrors the use of situated learning in games by highlighting how some games require the player to accomplish objectives within the rules, values, and norms of a new environment, where the player would need to understand, learn, and gain expertise over a certain set of skills, along with other procedures and principles that dictate the working of the new world. In the example given by Gee (2009), the author describes how a military game provides for the player, a set of equipment, and a world to operate in, however, the appropriate and efficient use and mastery of those things is in fact the learning that comes out of the gradual playing of the game. The mediation of the

player with the environment and its objects to achieve rules and norms dictated objectives is assumed to be the contextual and experiential learning that the user gains through situated learning (Gee, 2009).
Another instance of situated learning is highlighted in the findings by Hayes (2006) where the researcher tried to observe players who participated in a virtual simulator called *Second Life,* which is described as "a 3D online persistent space totally created and evolved by its users. Within this vast and rapidly expanding place, you can do, create or become just about anything you can imagine" (Second Life, 2021). It was found that the participants had learned to participate in the simulator's economy without any intervention by the researcher. The simulator required the participants to learn certain skills to be able to craft products which they could then sell for in-game money. A notable finding was that the money earned in the simulator had value outside the game as well, people constantly traded the game money of "real-life" money. Observing that, the research suggested highlighted the need for value creation for situated learning. The participants could self-motivate to learn the various mechanics of the simulator, as they perceived a value to be derived from it.

### Distributed Authentic Professionalism

Coined by Gee (2005) in their paper What Would a State of the Art Instructional Video Game Look Like? distributed authentic professionalism refers to the division of knowledge, activity, commands, and control between the player in the physical world and their digital avatar in-game. Gee (2005) showcases an example of the game Full Spectrum Warrior, which is an instructional video game intended to inform the player about the operative procedures of a U.S. Army soldier. The paper encourages the researcher to observe how the game distributes the set of responsibilities between the player and their virtual character, for example, the virtual character and their squad in-game are already aware of several real-life formations that the army uses, whereas it is the responsibility of the player to choose and decide when that particular formation will engage throughout the game. Similarly, the virtual squad in-game is aware of all the military commands and follows them immediately, however, it becomes the critical responsibility of the player to memorize those commands and use them appropriately in various situations. According to Gee (2005), this is exactly where the learning occurs. The game's manual explicitly informs the player that this is not a generic shooting game and the completion of it will rely on how professionally the player can think, act, plan, and execute like a soldier. Distributed Authentic Professionalism then becomes important in highlighting the need for balancing the information dispersion between the player and the virtual avatar and the environment (Gee, 2005).
**Motivation** - Although there exists research that attests to the contribution of motivation as an important factor in games, there happen to be varying opinions as to where the motivation can come from. Some have found motivation to be a part of the narration of the game, or the unfolding of the story, while some have demonstrated the existence of objectives, goals, and rewards as the generator of player motivation (Dondlinger, 2007). The research conducted by Amory et al., (1999) showcased that students of the first and second year appeared to like the graphics, audio engineering, and storyline as a factor for motivation in playing the game ahead, whereas other games that were simulation-based were played less by the same students. The research concluded by encouraging the use of factors that can help build intrinsic motivation for the students to play the game (Amory et al., 1999). Here intrinsic motivation refers to the intentional act of the players to play the game further out of their own free will, whereas extrinsic motivation is said to be gained from in-game system, goals, and rewards (Denis and Jouvelot, 2005). All research admits that motivation is pertinent to game design, and both intrinsic, as well as extrinsic motivation, should be considered throughout the building process.
**Contextualization** - The provision of a cognitive framework through narrative and descriptive contextualization in-game has shown to be helpful as an element of game design. In their survey, Dondlinger (2007) found five articles that supported this finding as well (Dondlinger, 2007). Narrative, descriptive contextualization was shown to help the participants situate themselves in the new environments while in games that required 3D navigation, it helped them build spatial relationships with the game. Here the reference to narrative contexts does not limit itself to textual or descriptive information, for example, in their research of 3D environments and 3D modeling, Dickey (2005) reported that the representation of in-game perspective as first-person helped the participants relate better with the environment and situate themselves better (Dickey, 2005).
**Rules, Objectives, and Goals** - Here the rules, objectives, and goals, though they are a part of the overall game context and narrative, they are a pertinent factor in game design themselves. Swartout and van Lent (2003) describe how the goals and objectives in a game are used by game designers to achieve engagement. They give an example of how game designers employ three levels of objectives for the player, wherein the first level, collection of tokens/keys can last for seconds, purchase of objects or the opening of safes can be the second level taking up to minutes of the gameplay, and finally the goal of defeating the end boss or saving the world could take up the entire gameplay and can the third and last objective. Swartout and van Lent (2003) observe that it is the interplay between these levels that give rise to engagement and consequently interest in the game.

They also suggest the combinatorial usage of these goals and objectives to emotionally immerse the players throughout the game (Swartout and van Lent, 2003).
According to Dondlinger (2007), it is key to distinguish between games that are educational and games that provide edutainment. The key difference between the two is observed to be interactivity, where the didactic nature of the educational games does not veil the intention of imparting learning; whereas the edutainment games focus more on the interest of the players to explore the game, where they end up learning and grinding skills by repetitive action to master some aspect of the game's mechanism, often called the 'skill and drill' format (Denis and Jouvelot, 2005). Educational games, on the other hand, demand a more serious progression of thinking and problem solving, where the system follows through with goals, objectives, and rewards. Both educational and edutainment games have shown to contribute gains in learning if applied appropriately. In addition to a consideration of learning theories in game design, below are some of the guiding principles that are either drawn from the above theories or are well established in the literature.

## Criteria for Designing Educational Computer Games

In the last section of this paper, the guidelines, theories, evaluations, and discussions regarding educational game design, learning environments, multimedia usage are combined to produce two sets of objective criteria for the design of game-based learning applications; the first deals with the aspects of game design that can enhance education in the form of learning and understanding, while the second deals with the elements of multimedia design that influences the application of learning.
The theories and guiding principles of game design, learning environments, and multimedia learning have been used to describe five areas that collectively address the first set of criteria for the educational design of the game and four areas that collectively address the second criteria of multimedia use for learning.

*Table 1. Criteria for the effective educational design of game-based learning applications, and elements that support the fulfillment of each criterion*

| *№* | *Criteria* | *Elements that support the fulfilment of the criteria* |
|---|---|---|
| 01 | **Content appropriateness** | Is in line with the curriculum and evaluation<br>Reflects subject matter honestly<br>Matches conventional teaching time of subject matter |
| 02 | **Player reliant gameplay** | Story progression through user action<br>Customization and personalization<br>Environment manipulation and player empowerment<br>Bifurcated responsibilities between the player and the in-game avatar |
| 03 | **Problem transmission and solving** | Order of the problems<br>Increasing Complexity<br>Solved work examples<br>Constructive frustration<br>Contributes to increasing expertise<br>Varied resources of information |
| 04 | **Learning through exploration** | Exploration possibilities<br>Encourages situated learning<br>Interactive environment<br>Sandbox features |
| 05 | **Goals and reward systems** | Generates Motivation<br>Rewards are proportionate to the difficulty<br>Tangible rewards<br>Rewards contribute to story progression<br>Placeholder for milestones |

*Table 2. Criteria for the effective multimedia design of game-based learning applications, and elements that support the fulfillment of each criterion*

| *№* | *Criteria* | *Elements that support the fulfillment of the criteria* |
|---|---|---|
| 01 | **Technology Selection** | Complements the educational objective<br>Complements the range of user abilities<br>Robustness of equipment and apparatus used<br>Flexibility towards the needs and the preferences of the learner |
| 02 | **Task Analysis** | Solved example and progressive complication<br>Achievable tasks through the multimedia operation<br>Complementary to the educational objective |
| 03 | **Content Representation** | An appropriate representation of educational information<br>Multiple inputs i.e. visual, audio, verbal, on-screen text<br>Structured order of information representation<br>Contributes to increasing expertise |
| 04 | **Interactivity** | Supports emergence of interest<br>Offers a range of interactions<br>Guided instructions<br>Meaningful Feedback |

## Conclusion and Discussion

This paper has used both the theories as well as the guiding principles in literature to develop and present these two sets of criteria to evaluate the elements of educational and multimedia design that influence the appropriateness of a computer game-based activity for learning. A review was provided that pulled together research on the design of learning environments, the use of multimedia in games, and the design of educational games. It was found that elements like content appropriateness, player-reliant gameplay, problem transmission and solving, learning through exploration, and the goals and rewards systems, are pertinent in the design of educational games (See Table 1). While an effective multimedia experience that can encourage learning needs to take into account elements like appropriate technology selection, task analysis, content representation, and the all-over interactivity of the experience (See Table 2).

The criteria generated through this research can contribute in designing better educational games as well as better learning environments that are assisted through multimedia. It will be an important step to analyze the findings of this paper by developing multimedia games through the criteria presented here and then performing a comparative analysis with the educational games that currently permeate the market, as well as compare the learning gained through the developed games with the learning provided by the contemporary methods of schools and colleges. However, that is the scope of future research.

## References


Amory, A., Naicker, K., Vincent, J., & Adams, C. (1999). The use of computer games as an educational tool: identification of appropriate game types and game elements. British Journal of Educational Technology, 30(4), 311-321.

Baddeley, A. D. (1986). Working memory. Oxford, England: Oxford University Press.

Bednar, A. K., Cunningham, D., Duffy, T. M., & Perry, J. D. (1992). Theory into practice: How do we link. Constructivism and the technology of instruction: A conversation, 8(1), 17-34.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. Educational researcher, 18(1), 32-42.

Buch, K., & Bartley, S. (2002). Learning style and training delivery mode preference. Journal of workplace learning.

Collins, A. (1995), 'Learning communities', presentation at the annual conference for the American Educational Research Association, San Francisco CA, April, 1995.

Collins, A., Neville, P., & Bielaczyc, K. (2000). The role of different media in designing learning environments. International Journal of Artificial Intelligence in Education, 11(1), 144-162.

Combs, A. W. (1981). Humanistic education: Too tender for a tough world?. The Phi Delta Kappan, 62(6), 446-449.

De Freitas, S., & Jarvis, S. (2006). A framework for developing serious games to meet learner needs.

Denis, G., & Jouvelot, P. (2005, June). Motivation-driven educational game design: applying best practices to music education. In Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology (pp. 462-465).

Dickey, M. D. (2005). Three-dimensional virtual worlds and distance learning: two case studies of Active Worlds as a medium for distance education. British journal of educational technology, 36(3), 439-451.

Dondlinger, M. J. (2007). Educational video game design: A review of the literature. Journal of applied educational technology, 4(1), 21-31.
Grabinger, R. S., & Dunlap, J. C. (1995). Rich environments for active learning: A definition. ALT-J, 3(2), 5-34.
Gee, J. P. (2005). What would a state of the art instructional video game look like?. Innovate: Journal of online education, 1(6).
Gee, J. P. (2009). Video games, learning, and "content". In Games: Purpose and potential in education (pp. 43-53). Springer, Boston, MA.
Grippin, P., & Peters, S. (1984). Learning theory and learning outcomes: The connection. University Press of Amer.
Hannafin, M. J. (1992). Emerging technologies, ISD, and learning environments: Critical perspectives. Educational technology research and development, 40(1), 49-63.
Hayes, E. R. (2006, May). Situated learning in virtual worlds: The learning ecology of Second Life. In American Educational Research Association Conference (pp. 154-159).
Huitt, W. (2001). Humanism and open education: Educational psychology interactive.
Juul, J. (2002, June). The Open and the Closed: Games of Emergence and Games of Progression. In CGDC Conf.
Kangas, M., Koskinen, A., & Krokfors, L. (2017). A qualitative literature review of educational games in the classroom: the teacher's pedagogical activities. Teachers and Teaching, 23(4), 451-470.
Kim, Y. J., & Pavlov, O. (2019). Game-based structural debriefing. Information and Learning Sciences.
Kolb, D. A. (1984). Experience as the source of learning and development. Upper Sadle River: Prentice Hall.
Lave, J., & Wenger, E. (1991). Legitimate peripheral participation. Situated learning: Legitimate peripheral participation, 29-43.
Mayer, R. E., & Moreno, R. (1998). A cognitive theory of multimedia learning: Implications for design principles. Journal of educational psychology, 91(2), 358-368.
Mayer, R. E. (2001). Multimedia Learning. Cambridge: Cambridge University Press.
Mayer, R. E. (2002). Multimedia learning. In Psychology of learning and motivation (Vol. 41, pp. 85-139). Academic Press.
Mayer, R. E., Fennell, S., Farmer, L., & Campbell, J. (2004). A personalization effect in multimedia learning: Students learn better when words are in conversational style rather than formal style. Journal of educational psychology, 96(2), 389.
Mayer, R. E. (2009). Multimedia learning (2nd ed). New York: Cambridge University Press.
McLoughlin, C., & Oliver, R. (2000). Designing learning environments for cultural inclusivity: A case study of indigenous online learning at tertiary level. Australasian Journal of Educational Technology, 16(1).
Merriam, S. B., & Baumgartner, L. M. (2020). Learning in adulthood: A comprehensive guide. John Wiley & Sons.
Pastore, R. (2016, March). Multimedia: Learner preferences for multimedia learning. In Society for Information Technology & Teacher Education International Conference (pp. 3015-3022). Association for the Advancement of Computing in Education (AACE).
Paivio, A. (1990). Mental representations: A dual coding approach. Oxford University Press.
Pavlov, I. P. (1927). Conditioned Reflexes: oxford University Press. London, UK [Google Scholar].
Plass, J. L., Chun, D. M., Mayer, R. E., & Leutner, D. (1998). Supporting visual and verbal learning preferences in a second-language multimedia learning environment. Journal of educational psychology, 90(1), 25.
Rieber, L. P. (2001, December). Designing learning environments that excite serious play. In annual meeting of the Australasian Society for Computers in Learning in Tertiary Education, Melbourne, Australia.
Schnotz, W., & Bannert, M. (2003). Construction and interference in learning from multiple representations. Learning and instruction, 13(2), 141-156.
Schraagen, J. M., Chipman, S. F., & Shalin, V. L. (Eds.). (2000). Cognitive task analysis. Psychology Press.
Schrier, K. (2006). Using augmented reality games to teach 21st-century skills. In ACM SIGGRAPH 2006 Educators program (pp. 15-es).
Second Life. (2021). Retrieved 19 May 2021, from http://secondlife.com/whatis/
Shaffer, D. W. (2004). Pedagogical praxis: The professions as models for postindustrial education. Teachers College Record, 106(7), 1401-1421.
Sorden, S. D. (2012). The cognitive theory of multimedia learning. Handbook of educational theories, 1(2012), 1-22.
Swartout, W., & van Lent, M. (2003). Making a game of system design. Communications of the ACM, 46(7), 32-39.
Sweller, J. (2005). Implications of Cognitive Load Theory for Multimedia Learning.
Thorndike, E. L. (1913). The psychology of learning (Vol. 2). Teachers College, Columbia University.

Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. Learning and instruction, 11(4-5), 381-419.
Watson, J. B. (1997). Behaviorism with a new Introduction by Gregory A. Kimble.
Wu, W. H., Chiou, W. B., Kao, H. Y., Hu, C. H. A., & Huang, S. H. (2012). Re-exploring game-assisted learning research: The perspective of learning theoretical bases. Computers & Education, 59(4), 1153-1161.

**Chaitanya Solanki**
Ph.D. Scholar, Indian Institute of Technology Hyderabad, India
*md19resch01001@iith.ac.in*
Chaitanya Solanki is currently a Ph.D. scholar at IIT Hyderabad where his area of research is a practical investigation into the use of computer game-based learning in the higher education of India. Chaitanya has previously completed his master's degree in visual communication from the National Institute of Design, Gandhinagar. Chaitanya has papers that are currently being published in the research fields of photogrammetry and design research.

**Deepak John Mathew**
Professor and Head of the Design Department,
Indian Institute of Technology Hyderabad, India
*djm@des.iith.ac.in*
Deepak John Mathew is a design professor and heads the design department at IIT Hyderabad. His research has been involved in several fields of design including mobility, fashion engineering, AI, games, and design education. Deepak has also been instrumental in initiating several exchange programs between international institutions from countries like the UK and Australia.