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Investigating the learning-theory foundations of game-based learning: a meta-analysis

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Abstract

Past studies on the issue of learning-theory foundations in game-based learning stressed the importance of establishing learning-theory foundation and provided an exploratory examination of established learning theories. However, we found research seldom addressed the development of the use or failure to use learning-theory foundations and categorized these learning theories into relative types and synthesized their development. We investigate this issue from the perspective of learning theories invoked to underpin educational computer game design and use based on the four types of learning theories: behaviourism, cognitivism, humanism and constructivism. Because the investigation needs to examine and analyse the results from a large number of independent previous studies, this study applied the meta-analysis method to present a more comprehensive description and discussion of the influence and implications of the findings. This study shows the distribution of development trends for the use of learning theory as a theoretical foundation, as opposed to those that fail to use learning theory in game-based learning, along with the distribution of types and principles of learning theories that used a learning-theory foundation. These new findings can supplement the results of previous studies with regard to the issue of learning-theory foundations in game-based learning. The contributions of this study for the issue of learning-theory foundations in game-based learning are discussed.

Keywords

game-based learning, learning theory, meta-analysis, pedagogy.

Introduction

Recent decades have seen the increased use of educational computer games as instructional strategies to assist student learning (e.g., Emery & Enger 1972; Martin 1979; Perrone *et al.* 1996; Squire 2002; Vereni-

kina & Herrington 2009). Technological developments such as the Internet and Web-based applications have accelerated this trend and game-based learning has recently become a significant focus of attention in the field of education (Garris *et al.* 2002; Gros 2007; Pivec 2007; Hong *et al.* 2009).

Previous studies of game-based learning mainly investigated its effectiveness; for example, focusing on students' learning performance when using computer games. Although some studies showed a positive effect of computer game-assisted learning (McGarvey 1986; Laffey *et al.* 2003), other studies presented the contrary

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results (Kim *et al.* 2002; Costabile *et al.* 2003). Some researchers, such as Vogel *et al.* (2006), have conducted meta-analyses to resolve whether the use of games and interactive simulations is more effective than traditional instruction methods, and under what contexts.

The effectiveness of game-based learning is a significant issue, and many researchers have stressed the importance of establishing a theoretical foundation for developing educational computer games and assisting game-based learning (Woodward *et al.* 1988; Thurman 1993; de Jong & van Joolingen 1998; Tam 2000; Garris *et al.* 2002; Hays 2005; Kiili 2005; Squire 2005). Kebritchi and Hirumi (2008) raised an issue in that past studies did not synthesize information on how established learning theories could be applied to guide research and practice. They reviewed 50 studies and 55 educational games to examine the pedagogical foundations behind modern educational computer games. Their results showed that 24 games were based on established learning theories (e.g. experiential learning) or their corresponding instructional strategies, whereas 31 games provided no explicit information concerning their pedagogical foundations.

Past studies have provided valuable insight into the issue of the learning-theory foundations in game-based learning. However, we found this research seldom provided the development of using or failure to use learning-theory foundations and categorized these learning theories into relative types and synthesized their development. We investigate this issue from the perspective of the learning theories invoked to underpin educational computer game design and use, based on the four types of learning theories: behaviourism, cognitivism, humanism and constructivism (Smith 1999). The two main investigations cover: (1) the development of the use of learning theory as a foundation in game-based learning, or lack thereof; and (2) the nature of links between using learning theory and game-based learning. Because the investigations need to examine and analyse the results from a large number of independent previous studies, a systematic review method via meta-analysis is employed to provide more comprehensive descriptions and discussions of the influence and implication of the findings. This method is similar to the work of Vogel *et al.* (2006), which explored the development of the positive vs. negative effectiveness of game-based learning.

In summary, regarding the issue of learning theories invoked to underpin educational computer game design and their use in game-based learning, this study conducts a meta-analysis to investigate both the development of the use of learning theory as a foundation in game-based learning, or lack thereof, and the nature of links between the use of learning theory and game-based learning. Specifically, this study investigates the following two research questions. (1) What is the developmental trend of the use of or failure to use a learning-theory foundation in game-based learning studies? (2) What are the common types and principles of learning theories used in game-based learning studies?

Literature review

Major learning theories and their representative principles

Adapted from Smith (1999), four main learning theories and their representative principles are chronologically presented and identified as behaviourism, cognitivism, humanism and constructivism (see also Amstutz 1999; Guy 1999; Merriam 2001; Jarvis *et al.* 2003; Conole *et al.* 2004; Kirriemuir & McFarlane 2004). Each learning theory has its own representative principles, which may be related to the surging interest in using computer games in learning.

First, behaviourism is primarily associated with the work of Edward Thorndike (1913) and Ivan Pavlov (1927) and was among the first learning theories to be developed. Behaviourists consider learning to be produced by stimulation and reinforcement. Behaviourism is based on three main assumptions: first, learning is manifested by a change in behaviour; second, the environment shapes behaviour; and third, the principles of contiguity and reinforcement are central to explaining the learning process (Grippin & Peters 1983; Shlechter 1991; Watson 1997).

The three representative principles of behaviourism are as follows. One is *direct instruction*, proposed by Zig Engelmann in 1964. This principle is a general term for explicit teaching using lectures rather than exploratory models such as inquiry-based learning. Next is the *programmed instruction*, proposed by Skinner in 1954, which typically consists of self-teaching with the aid of specialized textbooks or teaching machines that present materials structured in a

logical and empirically developed sequence. Programmed instruction allows students to progress through a unit of study at their own rates, checking their own answers and advancing only after answering correctly. The third one is the *social learning theory*, which was proposed by Bandura in 1965. This theory posits that people learn from one another via observation, imitation and modeling.

Second, cognitivists consider learning not to be simply stimulation and reinforcement, but to involve thinking (Moore & Fitz 1993). Cognitivism is based on two main assumptions: that the memory system is an active, organized processor of information and that prior knowledge plays an important role in learning (Merriam & Caffarella 1999). In the cognitive paradigm, the mind is essentially a 'black box' that should be opened and understood. The learner is viewed as an information processor (Learning Theories Knowledgebase 2008).

Cognitivism can be represented by the following principles. One is the *attribution theory*, developed by Weiner in 1974, which refers to the observation that learners attempt to explain the world and to determine the cause of an event or behaviour. This theory further divides the way people attribute causality into two types. External attribution assigns causality to an outside factor such as luck, whereas internal attribution assigns causality to factors within the person, such as their own level of intelligence or other variables that render the individual responsible for the event. Another is the *elaboration theory*, developed by Reigeluth in 1983, which argues that content to be learned should be organized from simple to complex (Learning Theories Knowledgebase 2008). Elaboration theory posits three values: when used properly, instruction can foster meaning-making and motivation; it allows learners to learn at their own speed during the learning process; and it facilitates rapid prototyping in the instructional development process. Another principle is the *stage theory of cognitive development*, developed by Piaget in 1969, which describes cognitive development as four distinct stages in children: sensorimotor, preoperational, concrete operational and formal operational. Another is the *theory of conditional learning*, developed by Gagne in 1965, which stipulates several different types or levels of learning. The significance of these classifications is that each different type requires a different type of instruction. Gagne identifies five major categories of

learning: verbal information; intellectual skills; cognitive strategies; motor skills; and attitudes. Different internal and external conditions are necessary for each type of learning.

Third, humanism emerged after the 1960s and focuses on the freedom, value, dignity and potential of persons (Combs 1981). According to Huit (2001), the central assumption of humanism is that individuals act with intentionality and values. This differs from the behaviourist notion of operant conditioning and the cognitivists' belief that the discovery of knowledge or construction of meaning is central to learning (Learning Theories Knowledgebase 2008). According to humanists, learning should be student centred and personalized, and the educator should act as a facilitator. Affective and cognitive needs are considered key aspects of learning, and the goal is to develop self-actualized individuals in a cooperative, supportive environment. Humanism involves the principle of *experiential learning* (Kolb 1984). Experiential learning requires no teacher and relates solely to the meaning-making process of the individual's direct experience. According to Kolb (1984), knowledge is continuously gained through both personal and environmental experiences. In addition, Kolb (1985) differentiated four different learning styles through their associations with different abilities. These four learning styles are diverger (prevalence of concrete experience and reflective observation), assimilator (abstract conceptualization and reflective observation), converger (abstract conceptualization and active experimentation) and accommodator (concrete experience and active experimentation).

Finally, constructivism considers learning to be an active, constructive process. Constructivists view the learner as an information constructor: individuals actively construct or create their own subjective representations of objective reality (Bednar *et al.* 1995). New information is linked to prior knowledge; thus, mental representations are subjective (Resnick 1987; Brown *et al.* 1989). The following are representative principles of cognitivism. *Social development theory* was developed by Vygotsky in 1962. Vygotsky focused on the connections between people and the socio-cultural context in which they act and interact in shared experiences (Crawford 1996). According to Vygotsky, humans use speech and writing to develop culture and employ these tools to mediate their social environ-

ments. Additionally, Vygotsky proposed the zone of proximal development (ZPD). The ZPD is the distance between a student's ability to perform a task under a teacher's guidance or with peer collaboration and his/her ability to solve a problem independently (Nassaji & Cumming 2000). According to Vygotsky, learning occurs in this zone. The process of helping students to learn is called scaffolding learning. *Problem-based learning* (PBL) was developed at medical schools in the 1960s and is characterized as an approach to learning in which students are given more control over their learning, are asked to work in small groups and, most importantly, acquire new knowledge only as a necessary step in solving authentic, ill-structured and cross-disciplinary problems representative of professional practice. This approach to learning arose, in part, from the sharp contrast between experiences at the beginning and end of medical school (Walker & Leary 2009). *Cognitive apprenticeship* is an approach in which students are enculturated into authentic practices through activity and social interaction (Brown *et al.* 1989). Thus, this principle assumes that it is important not only to solve problems in a learning environment that uses real-world contexts and immerses the learner in the culture of a particular practice, but also to allow learners to witness the practitioners of that culture solving problems and carrying out tasks. *Discovery learning* is a method of inquiry-based instruction that is considered a constructivist-based approach to education (Learning Theories Knowledgebase 2008). It is supported by the work of learning theorists and psychologists Jean Piaget, Jerome Bruner and Seymour Papert (Mayer 2004). *Case-based learning* (CBL) is also an offshoot of constructivism. CBL has its roots in the well-proven apprenticeship method of learning by doing. It is a student-centred learning approach that allows students to take greater responsibility and play a more active role in the learning process than they do in traditional classroom learning (Powell 2000). CBL usually uses a guided-inquiry method and provides more structure during small-group sessions (Srinivasan *et al.* 2007). The idea of CBL emerged from PBL. *Situated learning theory*, proposed by Lave and Wenger (1990), sees learning as a phenomenon, that is, learning occurs within formal education systems as a product of the social practices of its educational professionals (Fox 1997). Moreover, learning is embedded within activity, context and

culture. It is also usually unintentional rather than deliberate. Lave and Wenger (1990) call this a process of 'legitimate peripheral participation'. *Activity theory* is based on the anthropological/psychological theories of Leont'ev (1978)⁸ and Vygotsky (1978). Its utility when dealing with issues concerning the design and use of computer technology is described by Kuutti (1996). This theory is a very general philosophical framework for understanding the development of human culture and individual personality based on dialectical materialism. This theory can be seen as a framework for understanding the totality of human work and praxis and the deliberate processes of change (Bødker 1991). *Actor-network theory* was developed by Latour (1987) as an attempt to understand the processes of technological innovation and scientific knowledge creation (Learning Theories Knowledgebase 2008). Actor-network theory does not typically attempt to explain why a network exists; it is more interested in the infrastructure of actor networks, how they are formed and how they can fall apart (Learning Theories Knowledgebase 2008). Actor-network theory incorporates what is known as a principle of generalized symmetry; that is, a principle for how human and non-human (e.g. artefacts, organizational structures) agents should be integrated into the same conceptual framework and assigned equal amounts of agency. In this way, one gains a detailed description of the concrete mechanisms that hold a network together while allowing an impartial treatment of the actors (Giddings 2005).

Figure 1 and Table 1 present the classification and characteristics of the four learning theories and their representative principles.

How are learning theories instantiated within game-based learning?

Game-based learning can provide a rich learning context to help learners construct higher-level knowledge through ambiguous and challenging trial-and-error opportunities (Van Eck 2007). Additionally, Pivec and Dziabenko (2004) indicated that pedagogy was one of the major components of successful game-based learning. However, the connection between learning theories and game-based learning is still vague. Hirumi *et al.* (2010) suggested, 'For the most part, instructional designers know little about game development and

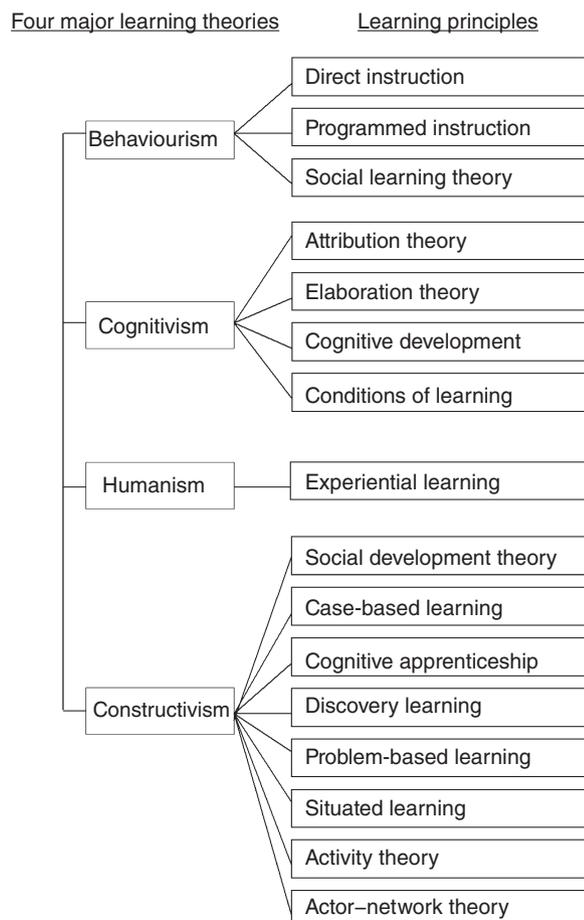


Fig 1 Classification of learning principles.

video game developers may know little about training, education and instructional design.’ One way to substantiate this argument is to demonstrate how effortlessly good games can be shown to fit into multiple of widely known and well-accepted instructional approaches (Becker 2007b).

Game-based learning is ‘learning through the game’, rather than ‘learning to play the game’. Therefore, based on the four types of learning theories, researchers use ‘game rules’, ‘game play’ and ‘game narratives’ (Ang *et al.* 2008) to explain the different aspects of game-based learning.

Game rules

Rules are one of the most prominent components of computer games. Frasca (1999) identifies two kinds of game rules: ludus rules and paidea rules. Ludus rules refer to games whose result defines a winner

and a loser, whereas paidea rules do not. For example, Civilization III (Squire *et al.* 2008) has no explicitly defined ludus rules; the goal of play is to achieve a certain status for one’s citizens in a continuum of satisfaction (i.e. happy, content, unhappy). Once one’s citizenry becomes unhappy, the city falls into disorder, production ceases and no food is stored.

Game play

Although game rules are an important component in computer games, game play is more than simply memorizing game rules (Ang *et al.* 2008). Game play involves interaction with a game through its rules, the connection between the player and the game, challenges and solutions, the plot and the player’s emotional connection with the plot (Egenfeldt-Nielsen *et al.* 2008). Paidea rules can not be broken; if the game rules that the game character can only move forward and backward, the player can not move in any other direction. Ludus rules are more flexible, and can be changed by the player to result in game play other than that intended by the designer (Ang 2006).

Game narratives

A narrative is a story that is created in a constructive format (such as a video game) that describes a sequence of fictional or non-fictional events. In game narratives, it included setting, character and action.

The instantiation of the four learning theories within game-based learning is described in the following.

Behaviourism instantiated within game-based learning. Behaviourism considers learning to be produced by stimulation and reinforcement; in addition, it proposes that learning is manifested by a change in behaviour.

From the ‘game rule’ aspect, in behaviourism the player needs to learn the paidea and ludus rules as the mechanism of the game. Namely, players need to know what can be done and what cannot be done. Second, from the ‘game play’ aspect, behavioural learning plays an important role in all kinds of games. For example, players press button A to move forward and button B to jump. Behavioural learning is especially useful in explaining autonomous responses elicited in certain situations. Players need to know their goals and achieve these goals through stimuli–reaction process, such as in

Table 1. Types and characteristics of each learning principle.

Learning principles	Characteristics of each learning principle
Direct instruction	Representor: Zig Engelmann in 1960s (Engelmann & Carnine 1982) Keywords: Direct instruction, feedback, prior knowledge, specific teaching goal, distributed practice
Programmed instruction	Representor: Skinner (1954) Keywords: Sequence material, individualized instruction, feedback, initial behaviour, terminal behaviour, self-learning
Social learning theory	Representor: Bandura (1977) Keywords: Social learning, modeling, observation, imitation, self-regulation
Attribution theory	Representor: Weiner (1974) Keywords: Self-ascription, external attribution, internal attribution, self-attribution, motivation, reward or punishment
Elaboration theory	Representor: Reigeluth (1983) Keywords: Simple to complex, learner centred, analogies, elaboration
Cognitive development	Representor: Piaget (1969) Keywords: Cognitive development, schema, assimilation, accommodation, disequilibrium, equilibration, sensorimotor period, preoperational period, concrete operational period, formal operational period
Conditions of learning	Representor: Gagne (1965) Keywords: Conditions of learning, transfer of learning, instructional event, diversity, reinforcement
Experiential learning	Representor: Kolb (1984) Keywords: Experiential learning, learning cycles, learning style, concrete experience, reflective observation, abstract conceptualization, active experimentation, diverger, assimilator, converger, accommodator
Social development theory	Representor: Vygotsky (1962) Keywords: Social culture, social development, zone of proximal development, scaffolding
Problem-based learning	Representor: None. Originally from medical school in 1960s. Keywords: Problem-based, authentic (real world), problem solving, teacher as facilitator, learner centred
Cognitive apprenticeship	Representor: Vygotsky (1978) Keywords: Learning by doing, cognitive apprenticeship, authentic practices, exploration, active learning, active thinking
Discovery learning	Representor: Bruner (1960) Keywords: Inquiry-based instruction, prior knowledge, discovery learning, trial and error
Case-based learning	Representor: None. Idea came from problem-based learning in 1990s. Keywords: Student-centred learning, critical thinking, problem solving
Situated learning	Representor: Lave and Wenger (1990) Keywords: Authentic activity, learning situation, situated learning, apprenticeship, legitimate peripheral participation, meaningful learning, socially shared, distributed
Activity theory	Representor: Leont'ev (1978) Keywords: Activity system, action, dynamic relations, mediated, structure, subject, objective
Actor-network theory	Representor: Latour (1987) Keywords: Actor-network, actors can be human or non-human

Tetris. Third, from the 'game narrative' aspect, behaviourists treat players as machines to be filled with information, and they are expected to passively absorb the narratives. This is usually accomplished through cut scenes or textual information from the nonplayer character (NPC) (Ang *et al.* 2008). Games like Vampire: The Masquerade (1998) is a multiplayer

game (Wikipedia 2011) in which the player that acts as the game master can 'possess' both player and NPCs, controlling their actions to further the storyline.

Cognitivism instantiated within game-based learning. Cognitivists consider learning not to be simply stimulation and reinforcement, but to involve

thinking (Moore & Fitz 1993). In the cognitive paradigm, the mind is essentially a 'black box' that should be opened and understood. The learner is viewed as an information processor (Learning Theories Knowledge-base 2008).

From the 'game rule' aspect, behaviourism is unable to explain all the rules in some games, especially in games that feature a more complex virtual world, which is usually composed of several micro-worlds. Super Mario Brothers 3 (1988) consisted many different micro-worlds (e.g. underwater world, desert, etc.) each of which have different game rules ranging from simple to complex (Ang *et al.* 2008). Players need to adapt to different situations through the original schema, which means the players are able to learn the rules by analysing new experiences in the context of previous situations. Cognitivism also stresses the importance of mental processing in that players need to predict or guess the rules through logical thinking, as in some puzzle in adventure games (Ang *et al.* 2008).

As for the 'game play' aspect, cognitivism emphasizes the context-dependent nature of knowledge where learning is promoted through scaffolding for task completion. In addition, player/learner control is an essential component of all games, players could play the game at their own pace or based on their mood. Some games include a 'warm-up' scenario, which gives the player basic knowledge about how the game is played and how it works. By interacting with the game, the player will observe, reflect and infer the rules underneath it. In terms of the 'game narrative' aspect, the setting can be sophisticated and involve emotional conflicts among the game characters. Rather than learning to behave in a certain way, the players need to learn the meaning of the setting, events, characters, and so on. Early on, players will try tactics from similar games they have previously played and will try to apply old experiences into the new context.

Humanism instantiated within game-based learning. The central assumption of humanism is that individuals act with intentionality and values. This differs from the behaviourist notion of operant conditioning and the cognitivists' belief that the discovery of knowledge or construction of meaning is central to learning. According to humanists,

learning should be student centred and personalized, and the educator should act as a facilitator. Affective and cognitive needs are considered key aspects of learning, and the goal is to develop self-actualized individuals in a cooperative, supportive environment.

From the 'game rule' aspect, humanism emphasizes that learners should engage in direct experience and focus on learning reflection. In humanism, ludus rules and paidea rules are more learner centred, which means the players could set their own rules to win or lose the game. As in the Pediatric Board Game (Sward *et al.* 2008), the players can decide whether to take cards in the next round or not. From the 'game play' aspect, the learner-centred approach is the most important component and players can play the games at their own pace and according to their mood. Global Conflicts: Palestine (Buch & Egenfeldt-Nielsen 2006) presents an example of 'game narrative' in which the player assumes the role of a journalist and collects information. Through interacting with the other characters, the player learns about the Israeli-Palestinian conflict and some other issues in the Middle East.

Constructivism instantiated within game-based learning. Constructivism focuses on the importance of socio-cultural context in understanding what occurs in the world through social interaction and constructing knowledge. 'Game rule' in constructivism stresses the interaction among players and games, which are socially constructed. From the 'game play' aspect, constructivism views learning as a social process and is not limited to the individual. Like simSchool (Zibit & Gibson 2005), a player enters the simulated classroom with a limited understanding of teaching practice; through repeated cycles of decision making, experimentation and refinement, the player builds expertise by developing new strategies and thinking like a teacher. It is a learning process that takes place through interaction with different kinds of students. From the 'game narrative' aspect, the individual's perception of the game world is constructed by players interacting with each other. In this case, the world is constructed based on comprehension of the entire social interaction. As in simSchool, players design tasks, and mimic students respond to the task, teacher interaction and their own internal emotional states

Table 2. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
<p>a. Must involve game-based learning theories as a primary condition, including behaviourism, cognitivism, constructivism or humanism.</p> <p>b. Must be publicly available or archived.</p> <p>c. Must have been published or presented no later than October 2009.</p> <p>d. Must include an identifiable learner level. All learner levels were admissible.</p> <p>e. Must involve situations in which students learned using computers.</p> <p>f. Must be of acceptable quality; only studies with no severe methodological flaws were included (see Shachar 2008).</p>	<p>a. Insufficient data for effect-size calculations.</p> <p>b. Involved simulations not used for educational purposes.</p>

according to their diverse personalities and learning preferences.

Method

The process involved the following: inclusion/exclusion criteria; data sources and search strategies; and data coding and extraction.

Inclusion/exclusion criteria

For inclusion in this meta-analysis, a study had to meet the criteria indicated in Table 2.

Data sources and search strategies

The studies included in this meta-analysis were located through a comprehensive search of the publicly available literature, primarily through manual electronic search of the databases, such as ACM Digital Library, EBSCOhost-Electronic Journal Service, Elsevier, Emerald Management Xtra 140, ERIC [EBSCOhost], IEL Online (IEEE, IET Electronic Library Online), JSTOR, ProQuest, SAGE, Science Citation Index Expanded, ScienceDirect OnSite, SpringerLink, Social Science Citation Index, Taylor and Francis Online Journals, Wiley InterScience and Wiley-Blackwell Journals.

Manual searches were conducted for *British Journal of Educational Technology*, *Computers and Education*, *Computers in Entertainment*, *International Journal of Learning Technology*, *Journal of Computer Assisted Learning* and *Simulation & Gaming*, and several conference proceedings such as the ACM SIGCHI International Conference on Advances in Computer Entertainment Technology, ACM SIGCOMM Workshop on Network and System Support for Games and Workshop

Exploring Ubiquitous Computing Entertainment. Although search strategies varied depending on the tool used, search terms included the keyword 'game' with 'pedagogy', 'instruct', 'learn', 'teach', 'training', 'entertainment', 'play', 'computer game', 'learning strategies' or 'design'.

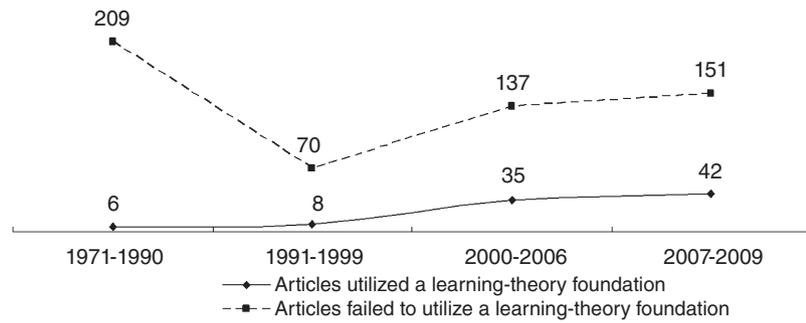
Our examination of research addressing the learning-theory foundations of game-based learning initially included 3834 results from previously search terms. We then used keywords from each of the representative principles (see Table 1) to focus on the major topic of our research; this narrowed the results to 869 studies but, given that search was conducted across multiple databases, some of these search results were repeats. The duplicate studies were deleted, leaving a total of 658 studies for analysis. Two researchers worked independently to confirm the presence of a learning-theory foundation in each study. Of the 658 studies, only 91 (13.83%) were based on learning theories.

Data coding and extraction

We developed a comprehensive codebook based on the criteria described previously and previous research (e.g. Lou *et al.* 2001, 2006; Bernard *et al.* 2004; Shachar 2008). A broad coding scheme was developed outlining two categories of substantive study features that might interact with the effects of game-based learning, as listed below.

Sixteen elements of the learning-theory foundations were coded including (1) direct instruction, (2) programmed instruction, (3) social learning theory, (4) attribution theory, (5) elaboration theory, (6) stage theory of cognitive development, (7) conditions of learning, (8) experiential learning, (9) social development theory, (10) CBL, (11) cognitive apprenticeship,

Fig 2 Distribution of the developmental trends of investigated studies. Note: After 2000, new technological developments replaced the multi-user dungeon with online games.



(12) discovery learning theory, (13) PBL, (14) situated learning theory, (15) activity theory and (16) actor-network theory (see Fig 1 and Table 1).

Study features were coded independently by two researchers and then compared for reliability. The inter-coder agreement rate by two raters for 91 studies was 91.28%. Disagreements between the two coders were resolved through discussion and further review of the disputed studies. An exclusion study was performed based on the inclusion/exclusion criteria. From the results, 91 studies met all inclusion criteria and thus were included. To provide a clear overview of game-based learning studies that used a learning-theory foundation, descriptive statistics were used to present the collected data.

Results

Overall, the studies using a learning-theory foundation included 21 studies from published conference proceedings, two from book chapters, 58 from published journals and ten studies from game reports. The results of the meta-analysis were analysed further, as discussed in the following.

Distribution of developmental trends of investigated studies

Figure 2 presents the distribution of developmental trends in using or failing to use a learning-theory foundation in game-based learning studies. In terms of the trend for using a learning-theory foundation, six were published from 1971 to 1990, eight from 1991 to 1999, 35 from 2000 to 2006 and 42 from 2007 to October 2009, suggesting that use of learning-theory foundations for game design has been increasing over time based on the development of technology (e.g. the Internet). On the other hand, of the studies that failed to use a learning-theory foundation, 209 were published from 1971 to 1990, 70 from 1991 to 1999, 137 from 2000 to 2006 and 151 from 2007 to October 2009.

Distribution of learning-theory types and their principles

Figure 3 shows that, of the 658 studies, the learning-theory foundations of 12 studies could be classified as being based on behaviourism, 17 as cognitivism, 25 as humanism and 48 as constructivism, and 567 could be

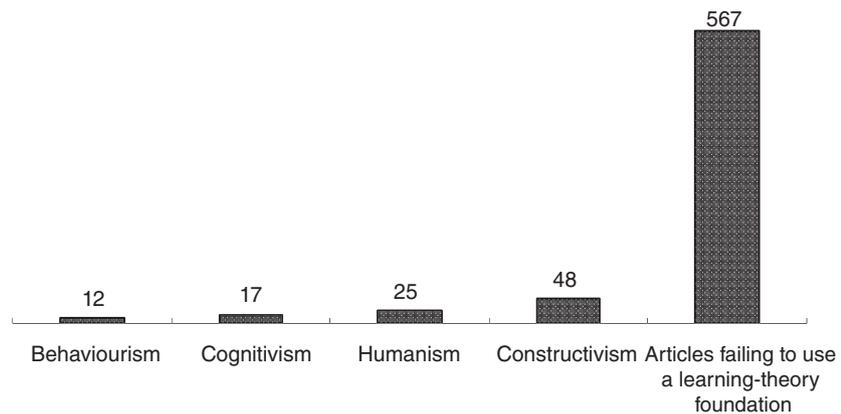


Fig 3 Types of learning theories.

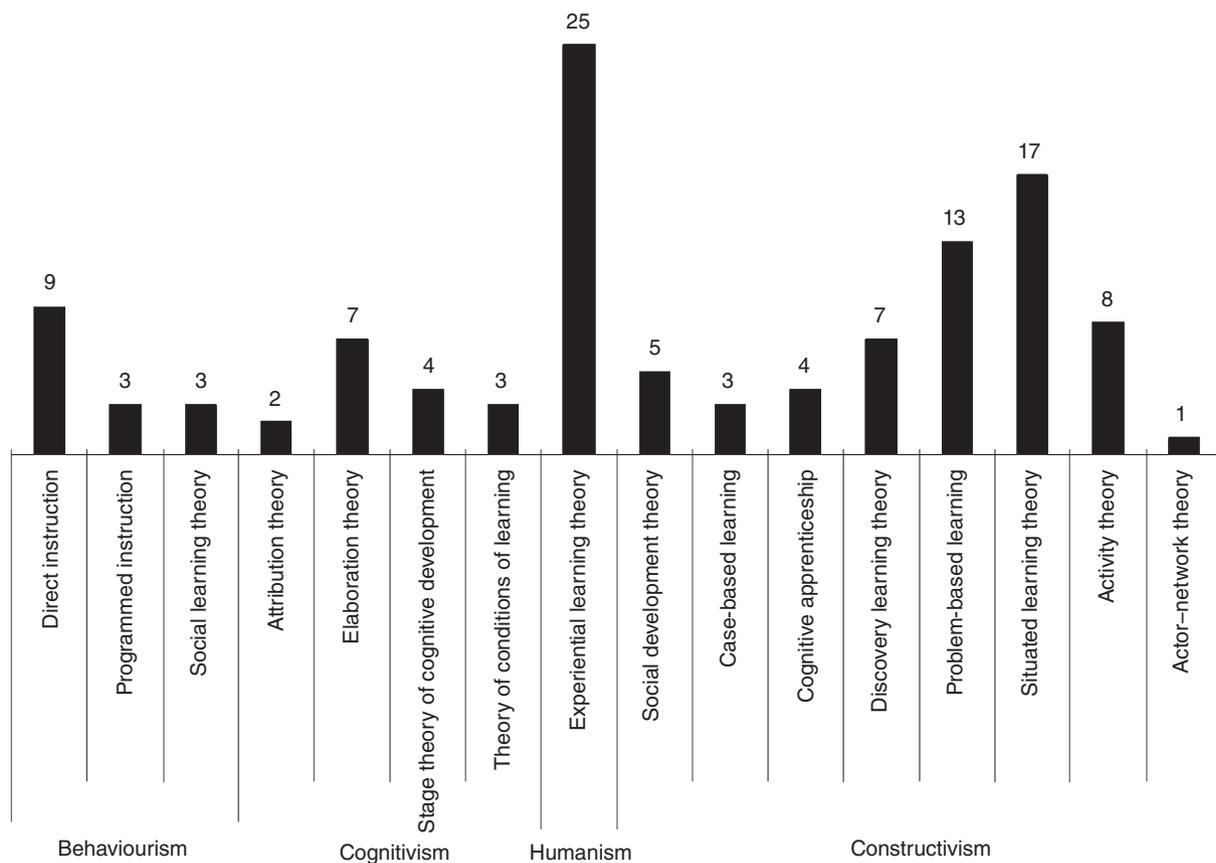


Fig 4 Types of learning principles.

classified as failing to use a learning-theory foundation. Therefore, most studies with a learning-theory foundation were classified as being based on constructivism, followed by humanism, cognitivism and, finally, behaviourism.

Behaviourism encompasses three principles of learning that appeared with the following frequencies: nine studies incorporated direct instruction; three incorporated programmed instruction; and three incorporated social learning theory. Cognitivism comprises four principles, which appeared with the following frequencies: two studies incorporated attribution theory; seven incorporated elaboration theory; four incorporated a theory of cognitive development; and three incorporated the theory of conditions of learning. Humanism emphasizes experiential learning, and 25 studies incorporated this principle. Constructivism includes eight principles of learning, which appeared with the following frequencies: five studies incorporated social development theory; three incorporated CBL;

four incorporated cognitive apprenticeship; seven incorporated discovery theory; 13 incorporated PBL[§]; 17 incorporated situated learning theory; eight incorporated activity theory; and one incorporated actor-network theory. Figure 4 presents these results.

In general, studies using learning-theory foundations disproportionately reflected constructivist principles; the principles represented most frequently were experiential learning theory (25 studies), situated learning theory (17 studies), and PBL (13 studies).

Discussion

Distribution of developmental trends of investigated studies

Used learning-theory foundations vs. failed to use learning-theory foundations

More published studies failed to use learning-theory foundations than used learning-theory

foundations. The use of game-based learning has been an important trend in the field of education (Becker 2007a; Moreno-Ger *et al.* 2008), but researchers rarely focus on the learning-theory foundations of these educational games. Our results revealed that 567 studies failed to use learning-theory foundations in their analyses, as opposed to only 91 studies, which were founded on learning theory. The results were similar to those of an exploratory study by Ke (2009), which explored game-based learning activities with or without a learning-theory foundation using qualitative and quantitative meta-analysis and found little research concerning the learning-theory foundations of game-based learning.

Development trends based on technological development

Publication of relevant studies was concentrated between 1971 and 1992. As indicated by our results, most studies that used (or failed to use) learning-theory foundations were conducted between 1971 and 1992, primarily because the study of computers in education largely fell under the catch-all heading of *computer-assisted learning*. During the 1980s, the number of computers used in American schools increased (Becker 1983), which prompted the publication of a greater number of studies. Following 1992, the development of technology coincided with the term *computer-assisted learning* being replaced by terms such as *computer-based learning*, *Internet-based training* and *Web-based training*.

Changes in technology from 1980 to 1999 resulted in the publication of fewer studies that used or failed to use learning-theory foundations. While creative game techniques were evolving during the 1980s, an enthusiastic emphasis on applying games to enhance learner interest overshadowed research on effectiveness (Randel *et al.* 1992). The scant research during this period may be related partly to the reduced support for research projects in which technology was being moved to the classroom and evaluated (U.S. Congress, Office of Technology Assessment 1988).

Through the gradual maturation of technology, studies using learning-theory foundations increased after 2000. We found that the number of studies using learning-theory foundations increased over time,

especially after the year 2000. In fact, since the 1990s, six factors have had a significant impact on instructional-design practices (Reiser 2001): the performance technology movement, constructivism, electronic performance support systems, rapid prototyping, increasing use of the Internet for distance education and distance learning and knowledge-management endeavours. These factors help explain the changing distribution of studies. Additionally, Becker (2007a) found a significant increase in the frequency of computer use in education between 1998 and 2003, which may also have had an impact on the distribution of studies. It is notable that games have evolved over time. Games produced between 1990 and 2000 were primarily single-player PC games or multi-user dungeons but, with the development of the Internet, after 2000 online and mobile games became more popular.

Distribution of learning-theory types and their principles

With the development in learning theory, more studies have focused on constructivism and humanism than on behaviourism and cognitivism

For most of the 20th century, the development of learning theories followed historical trends reflecting the emergence of behaviourism, cognitivism, humanism and constructivism. According to Wikipedia (2010), computer games were first developed in 1961, and more recent studies with learning-theory foundations focused on constructivism and humanism in accordance with the development of technology.

In recent years, learner-centred approaches to teaching and learning have been gaining momentum in conventional classrooms and online learning environments (Dickey 2005; Kebritchi & Hirumi 2008). In fact, a number of game designers have recommended using instructional support including explanations of game procedure, hints, advice and feedback within learner-centred instructional approaches such as experiential and discovery learning strategies to facilitate game-based learning (Leemkuil *et al.* 2003). Humanism and constructivism both stress the importance of learner-centred education; therefore, studies using these learning-theory foundations are more numerous than those incorporating the other two learning theories, especially for experiential learning.

Analyses also revealed that situated learning theory and PBL were often used as the basis of game design, as opposed to experiential learning, which was used most often in studies with learning-theory foundations.

Conclusions

In terms of the issue of a learning-theory foundation in game-based learning, previous studies (i.e. Kiili 2005; Kebritchi & Hirumi 2008) provided valuable insight from the perspective of the importance of learning theories, along with an exploratory examination of established learning theories. This study supplements that view by presenting new findings on the developmental trends of use of learning theory as a foundation opposed to those that fail to use in game-based learning and the nature of links between the learning theories referenced and game-based learning. The findings contribute to the understanding of the issue of learning-theory foundations in game-based learning as follows:

First, previous studies neglected developmental trends in the use of learning theory as a foundation opposed to those that fail to do so in game-based learning. However, this study not only showed three different developmental trends during different decades, but also showed that the patterns of use vs. lack of use changed significantly over time with the evolution of technology; also, this study found that studies which failed to use a theoretical foundation always outnumbered those which used a theoretical foundation. This reflects a general failure to account for the importance of establishing a theory. Hence, we suggest future research should combine different academic fields (i.e. education, psychology, computer science and engineering or management) and even include specialists from industry to collaboratively develop a game-based learning system or platform to increase the proportion and use of learning-theory foundations in game-based learning.

Second, regarding the nature of links between the referenced learning theories and game-based learning, previous studies applied one type of learning theory to the design or use of game-based learning but not others. However, this study investigates the distribution of four different learning theories (i.e., behaviourism, cognitivism, humanism and constructivism) and finds that the majority of previous studies focused on constructivism and humanism rather than behaviourism and cognitivism, reflecting the tendency of researchers

to adopt the more contemporary learning theories. More importantly, another of the current research had to do with the concentration of principles of learning theories. The three most commonly used learning principles were experiential learning, situated learning theory and PBL, which implies that most researchers tend to adopt contemporary learning theories and their principles. However, to gain a richer understanding of the issue of learning theories in game-based learning, we still suggest that researchers should apply the types and principles of behaviourism or cognitivism, or combinations of different types in future research.

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§Note: Some small corrections have been made to this article on 27 Dec 2011 after first publication online on 15 August 2011; a text reference to Leontjew A.N. (1978) has been corrected to Leont'ev A.N. (1978), and '... three incorporated PBL; ...' has been corrected to '... 13 incorporated PBL; ...' in the text description below Figure 4.

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