Challenging Games or Digital Textbooks? Content analysis of message structure and learning principles in serious games

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Abstract

Previous studies on game-based learning have proposed many factors that make video games good learning tools. This study uses content analysis to assess whether these theories are applied to the designs of web-based games for learning. The samples for this study are 90 pro-environmental video games randomly sample from the internet. Results from this study showed that despite the assumptions that video games are different from textbook in presenting knowledge not as fact, but as interactive problems to solve. This study found that a majority (47.13%) of the games presented their educational messages in a mixture of facts and open-ended problems. The games also incorporated different degrees of learning principles suggested by previous studies into their design. This study argues that we might be able to predict the learning potential of a serious game by measuring the way intended messages are structured in game instructions.

Introduction

Over the past 25 years, video games have grown from technological toys for a handful of software engineers to popular entertainment among American households. A national survey conducted by the Pew research center showed that 97% of American teenagers aged 12 -17 have played video games, and 50% of teens played video games "yesterday" (Pew Internet & American Life Project, 2008). Video games' popularity has attracted both concerns over its effect and hopes for its potential.

Some researchers fear that exposure to violent video game will have negative effects on users, leading to various research on whether violent graphics and narratives will make video game players more aggressive (e.g. Anderson & Bushman, 2001; Lachlan, Smith & Tamborini, 2005; Schutte, Malouff, Post-Gorden & Rodasta, 1988; Sherry, 2001). Other researchers are more optimistic about the effect of video game on players. They see the popularity of video games as an opportunity to reexamine pedagogy theories and methods (Garris, Ahlers & Driskell, 2002; Gee, 2003). These researchers argue that if video games can motive and influence user behavior, it can be used to supplement or replace textbooks for education, training, and simulation purposes.

The different focus on video game effects has led to incomplete understanding of video game contents. Previous content analysis of video games focused on problems such as violence and gender representations, but few studies have examined other pro-social contents

such as educational values which are also found in video games. At the same time, it is estimated that more than 125 million US dollars are invested into developing games for learning every year (Blunt, 2007), but few studies have studied if pro-social contents have the same effect on users as the negative contents (Ritterfeld, Cody, & Vorderer, 2009). Without comprehensive knowledge about video games contents and few evaluation of other effect besides violence, teachers, parents, and policy maker will have trouble deciding whether video games should be used in school curriculums, or which games are better suited for certain goals.

In order to untangle some of these problems, this research has created a content analysis scale to assess the message structure and learning principles found in web-based serious games. Previous researchers have studied why video games are good for learning (Gee, 2003; Shaffer, Squire, Halverson, & Gee, 2005; Squire, 2003). Some have proposed criteria for assessing the learning potential of video games (Gee, 2005), but to my knowledge, there has been no studies that applied these assessments to existing video games.

Drawing from pedagogy theories of game-based learning and problem-based learning, this study found that the amount of learning principles could be predicted by measuring the message structure in game instructions. In other words, we can predict the educational "potential" of a serious game by assessing its instructions which consists of goals, values, rules, and controls. This study can provide teachers and parents with a preliminary

assessment method to determine which games to incorporate into education; its implications can also guide future designers to exert the learning potential of video games.

Literature review

Video Games and Learning

The use of games for learning is not a new trend, Piaget (1972) has argued that game-playing is a vital part of cognitive development, children learn about their identity and environment through play, not adult instructions. Games can provide a stable, logical situation for children to apply their reasoning (Weininger, 1978). Earlier pedagogy theorists believed that games can motivate constructive learning through immersing the learner in simulated situations, and encourage repeated trials to stimulate learning from previous experience.

This tradition of considering games as learning facilitators led many education researchers to notice the growing popularity of video games in the 1980s. Some researchers were interested in how we can make video games for educational purposes, others focused on what education could learn from the success of video games. The focus on making video games for self-motivated learning and assessment are known as “serious game” research. Serious games are defined as games with “explicit and carefully thought out educational purposes and are not intended to be played primary for amusement” (Micheal & Chen, 2006:

21). Serious games have been used for many purposes, as part of school curriculums, in professional training of surgeons (Rosser et al., 2007) and solders, and simulation for aircraft pilots (Micheal & Chen, 2006). Squire and Barab (2004) experimented with using video game to teach history in classrooms. They found that video games engaged students in active learning. With some instructor guidance, the students were able to draw structural conclusion about the relationship between history, geography, economics, and politics.

Simulations in games have several advantages as they allow users to visualize a system at work. Users can observe a system's behavior from different perspectives and across time. Users can also manipulate otherwise unalterable variables, pose hypothetical questions to the system, and further compare the simulations to their previous understanding of that system (Squire, 2003). For example, in the game *Simcity*, the intricate dynamic relation between urban design, government budget, and public opinions are transformed into stats and graphical symbols, allowing users to experiment and play with different adjustments. Through playing with different policies, users can learn how one factor affects other factors, and how to design an optimal policy to meet various demands and goals. Users may even compare their in-game experience to their actual observation of urban dynamics, and come up with opinions on how to improve their city.

Aside from serious game studies, some education researchers saw the popularity of video games as a chance to reexamine existing education methods. Malone (1981) found

three factors that made games engaging: challenge, fantasy, and curiosity. He argued that schools could learn from video games by providing clear goals that are meaningful to learners, constant feedbacks to help learners learn about their progress, adjustments to fit the learner's progress, and engaging fantasy and surprises. Gee (2003) compared video games structures to learning principles and argued that popular video games are good learning tools with built-in assessments. Players do not seek simple games that they could easily master; instead they seek complex games that challenge their mental ability and physical skills.

Gee's (2003) central arguments is that video games are a type of "semiotic domains," which he defines as a set of things that can communicate context-specific meanings, for example words, sound, pictures, or gestures. Mastering a game involves learning the knowledge and skills, along with the ability to use available resources. Users learn these knowledge and abilities through interacting with the game design and with people who share the same semiotic domain. In short, video games can facilitate learning through providing problems that encourage players to solve through exploring simulated environments and interacting with other people. This learning process corresponds to the theoretical arguments of problem-based learning.

Problem-based learning

Problem-based learning is a constructive learning approach that places learner

experiences at the core of the learning process. In comparison to traditional method of learning that focused on fact memorization. The core premise is that instead of teaching facts, learning would be more effective if challenging problems were provided for the learner to solve. The problems can be provided by instructors or drawn from the learner's life experiences. Learners are encouraged to work together to solve the problems. If a proposed solution fails, learners are encouraged to reflect on this experience and come up with improved solutions. It has been argued that knowledge will be constructively created and learned in this process of problem-raising, communication, and learning from experience (Hmelo-Silver, 2004). Studies have shown that this method is effective because students are more likely to remember their own experience and apply these knowledge in future situations (Barab, Barnett, & Squire, 2002; Prensky, 2000). In summary, problem-based learning emphasizes six characteristics: 1) student-centered learning; 2) small learning groups; 3) teachers act as facilitators; 4) problems as focus and stimulus of learning; 5) problems are vehicles for practicing skills; 6) new knowledge is acquired through self-directed learning (Barrows, 1996).

Some critics warn that promoting problem-based learning may imply that instructors are unimportant in the learning process. They argue that learners must have sufficient prior knowledge before partaking in this constructive learning process. Without guidance, learners may result in disorganized or incomplete knowledge (Kirschner & Sweller & Clark, 2006).

However, supporters of problem-based learning argue that problem-based learning is not unguided education. Instead, instructors play an important role in fostering collaboration, facilitating reflection, and planning supplementary activities (Squire, 2003). Problem-based learning has gain wide popularity among education scholars and practitioners since the 1960s, and is officially included into the U.S. National Science Educational Standards in 1996.

Based on arguments similar to problem-based learning, researchers of game-based learning have argued that video games are good learning tools because they convey message and knowledge not through facts, but through challenging problems that invite players to solve. The assumption is that video games which present interesting problems are more enjoyable and better learning tools than those that merely present facts. This study seeks to examine this assumption by assessing the relation of problem-based messages to the amount of learning principles in serious game design.

Learning principles in video games

Many studies have attempted to identify learning principles in video games (eg. Garris et al., 2002; Gee, 2003; Prensky, 2001; Squire, 2003; Shaffer et al., 2005). However their results have been inconsistent. This may be because some studies focused on specific genre of games (Malone, 1981; Squire & Barab, 2004), while others discussed video games as a whole and identified learning principles from a large group of different games (Prensky, 2001; Gee,

2003, 2005b). In order to provide a more general theoretical framework for studying educational video games, Shaffer et al. (2005) reviewed past studies and combined the various principles into four general principles: *Situated meaning*, *Effective social practice*, *Identity*, and *Shared value*.

Situated meaning is a common principle identified by many researchers. Unlike textbooks or classroom learning, video games have the ability to present knowledge within simulated context (Shaffer et al., 2005). For example, while one can learn facts about flying an airplane from books, these facts have little use to the learner if they do not intend to fly an airplane. But a video game simulation can provide the situation in which the learner 'must' flying an airplane in order to proceed in the game, this simulated context creates a demand to learn, and the learner can understand where each knowledge are applied through their simulated flying experience. "The rich virtual worlds are what make video games such powerful context for learning (Shaffer et al., 2005: 106)." In other words, knowledge is presented within context, and meanings are derived from experience.

Effective social practice can be generally defined as applying learned knowledge to the real world. Unlike classroom learning which has little impact outside of the classroom, players often actively search for information related to their game and contribute their knowledge to online discussion forums. Players may gain reputation or sometime even monetary reward from contributing their knowledge.

Identity principle is defined by Shaffer et al. (2005) and Gee (2003) as the ability to take on and experiment with different identities "in such a way that the learner has real choices (in developing the virtual identity) and ample opportunity to meditate on the relationship between new identities and old ones (p.67)." Video games allow learners to experiment with different identities, to make decisions from a different perspective, and to reflect on the effects of their decisions.

Shared values describe video game's ability to build communities or affinity groups. Because video game presented meanings within specific contexts, its users often have shared knowledge or feelings. Sometimes users will organize online or offline gatherings to network with one another, which can affect future cooperation or competition in their games (Jenkins, 2006). Because shared values can be created by design or player interactions, this study focuses only on design features that aim to facilitate shared value, such as multiplayer options, discussion board, and score rankings.

This research attempts to apply these four general learning principles in assessing the learning potential of serious games. I also included assessment of guidance designs because problem-based learning researchers have argued that guidance is an important factor affecting learning effect. Guidance designs are defined as tutorial sections that allow players to learn and test their ability before actual game-play, help functions for players to reference if they ever need it during game-play, and instant feedbacks on player action so the players can

immediately ‘correct’ their decisions.

Even though these are common learning principles identified by many previous researchers, to my knowledge there has been no studies which constructed a scale for measuring these principles in video games.

Message Structure

One of the main goals of education is to communicate knowledge, values, and skills, which are often communicated through messages. The independent variable for this study focuses on how these knowledge, values or skills are structured as instruction messages in existing web-based serious games.

Previous studies on game-based learning often contrasted video games to textbooks in their method of communicating messages. One such comparison is that textbooks focused on conveying facts while video games focused on the experiences of solving context-situated problems (Shaffer et al., 2005). This does not mean that textbook do not present knowledge as problems, nor does it mean that video games do not present knowledge as facts. This kind of comparison simply implies that knowledge-carrying messages can be categorized within two distinct categories: *Fact-based messages* and *Problem-based messages*.

Fact-based messages are usually presented as a ‘correct’ answer to a question. The learner’s role is to accept this answer and memorize it. Good learning is assessed by whether

learners can match the correct fact to test questions. Fact-based messages are absolute with little ambiguity; they do not require learner reflection on personal experience to understand its meaning, and they do not encourage learner exploration to find alternative answers.

On the other hand, problem-based messages encourage exploration and often do not provide correct answers before the learner's experience. It is often presented as a set of instructions to solve a problem, or simply a goal to reach without specific instructions. The knowledge, values, and skills are learned through reflecting on one's experience in the process of solving problems or to reach a certain goal.

It has been argued by researchers that the learning-by-doing of problem-based learning is more effective than fact-based memorization (Barab et al., 2002; Lave & Wenger, 1991; Prensky, 2000). But most of the studies used survey or interview methods in the classroom, no content analysis have been applied to assessing these two forms of message in existing video games. This study provides a measurement scale for assessing the message structures in video games.

Hypothesis and research questions

A series of research (e.g Gee, 2003, 2005a; Squire, 2003) have argued that good video games are learning tools which communicates intended message through problems instead of facts. Since most serious games are designed with educational intentions in mind, the first

goal of this research is to assess whether related learning theories are incorporated in them. Therefore my first research question is:

RQ1: What proportion of existing environmental games presented their message in problem-based messages? And what proportion in fact-based messages?

Researchers have argued that the factors which make a video game popular are similar to the learning principles of effective learning (Gee, 2003, 2005). Better games will incorporate more learning principle that makes them engaging and suitable for educational purposes (Gee, 2005b). My second research question is:

RQ2: What proportion of environmental serious games incorporated the learning principles? What is the distribution of learning principles among existing serious games?

As noted in the literature, the arguments for game-based learning is that games can provide a simulated experience in which the learner learns through solving challenging problems (Gee, 2003, 2005; Prensky, 2000; Shaffer et al., 2005). Therefore my main hypothesis for this study is:

H1: Games that use more problem-based messages will incorporate a higher number of learning principles than games that use fact-based messages.

Method

Content analysis is suitable for studying the message structure of serious games because it focuses on the content rather than individual experiences. Video games are interactive media; therefore a player's experience will not only be affected by the game's design, but also by the player's previous experience, familiarity with the game, preference, or other environmental factors. Content analysis can control these differences by focusing on the content and design. However, its advantage is also its weakness. Content analysis cannot measure the effectiveness of a game as it varies according to different players, content analysis can only measure the "potential" effectiveness of a video game from the design perspective.

Sampling

Since this study focuses on assessing web-based serious games, the sampling population should be all the existing serious games on the internet. But several characteristics of the internet make defining the population difficult: First, the internet is not static but in flux, new contents are added every moment while old contents are abandoned (Riffe & Lacy & Fico,

2005, p.118). Second, we rely on search engines to gather relevant data, yet each engines use different algorithms that result in different results. Third, many search results are duplicate data or reference to the same data. These characteristics makes it difficult to draw a clear sampling frame, therefore it is only possible to use a purposive sampling technique.

I used *Google* as my search engine for purposive sampling, because *Google* is the largest search engine in the world, accounting for 65.7% of the market share (Comscore, 2009DEC). This allows me to find the games that are most likely to be found by most internet users. In other words, this decision is made to purposively sample for the most accessible environmental games on the internet.

Because there is no previous research that sampled web-based video games on environmental issues, the keywords for this study were identified using web tools that measure search frequencies. Due to resource constraints, the keyword search was limited to English keywords. I used Google AdWords, a website tool that shows the frequency of different keywords to identify the keywords for this research. The most frequently searched keywords related to this study are: Environment games, earth day games, and sustainable development games.

The more general keywords were selected instead of specific keywords such as climate change, wildlife conservation, or energy efficiency for two reasons. First because the general concept of environmentalism contains the more specific issues, thus I will be able to cover a

diversity of specific issues using the most general term in my search. Second, because this study is interested in the message structure (content structure) rather than the specific content topics, therefore it is unlikely that difference in topics will affect whether a message is presented as challenging problems or knowledge facts.

I collected the video games found in the first seven pages of search results, because research have shown that the average internet users rarely go pass seven pages in a keyword search. Therefore including results from the first seven pages will allow this research to cover the games that are most likely to be accessed by users. A total of 257 games are collected and a random sample of 90 games was drawn for this study.

Data Processing

Because this study analyzed web-based video games, the three coders could gain access to them directly through internet connection. There are two risks involved in using web-based content. First, the content could be removed or changed during the research period. In that case, it is considered no longer accessible to most users and is excluded from this study. The second risk is that certain content are inaccessible without registration or purchase. In such cases, we coded the available demo version.

Coders were asked to play through each game, performing according to the game instructions to ensure that they experienced the intended messages. Due to resource limits, if

the game exceeds 20 minutes, only the first 20 minutes were coded. This time limit is acceptable because serious games often have classroom use in mind when they are designed, so they rarely expand more than 10 minutes.

Variables Definitions

Message Structure (IV). Environmental messages in video games can be communicated through many different forms such as text, video, audio, or more implicit score and rewards. Since video and audio messages require subjective interpretation to perceive, this study only focused on message structure in textual instructions.

Pro-environmental is defined in the oxford English dictionary as: “of or pertaining to the environment”and“not harmful to the environment.” This study takes the second definition, defining Pro-environmental as a broad term that includes nature conservation, energy efficiency, waste management, pollution control, etc. A list of key words and definitions were provided to the three coders in case of confusion.

This study focused on game instructions because instructions are often the textual description of rules, goals and values, which are some of the defining factors of games (Caillois, 1961). Therefore it is possible to assess underlying value and messages of a game through assessing its instructions. This study distinguished four nominal measurements for message structures: 0=no textual instructions or only games control description. 1=Fact-based.

2=Equal fact and problem-based 3=Problem-based.

If the introduction does not exist, or no textual messages are presented, it is coded as *none*. If it has pro-environmental goals and provided methods to achieving that goal, leaving little room for player exploration, it is coded as *fact-based*. If the instruction has pro-environmental goals, but encourages the player to explore methods to achieve that goal, it is coded as *equal fact and problem-based*. Sometimes the instruction is neutral with no value judgments, or that it is in satirical form with an anti-environmental goal. Neutral or satirical goals not only require players to explore methods, but also derive its hidden message through self-reflection; therefore it is coded as *problem-based*.

Learning Principles (DV). The categories for learning principle are adapted from Shaffer et al.'s (2005) learning principles: *Situated meaning, Effective social practice, Identity*, and *Shared value*. This study adds an additional principle: *Guidance*. The presences of these five learning principles are assessed by coders on a two point scale. 0=none 1=present

The five constructs are broken into smaller variables for operational purpose. Coders identified *situated meaning* by assessing whether a story or background is provided? And whether the game has a simulated environment? *Effective social practice* is assessed by whether the game content referenced real world action or influences? And whether the game

provided hyperlinks to additional information on real world information? *Identity* is measured by whether the game has avatars? And whether players attain a character or certain roles in the game? Because *shared value* can be created by both game design and player interactions, we can only focus on the design aspect. *Shared value* is assessed by whether there are multiplayer options? And whether there is a discussion board or forum that promotes player communication? *Guidance* is assessed by measuring whether there is tutorial or practice option before actual game-play? And whether help or hint functions are provided during game-play? Also whether the game provided instant feedback for the player to "correct" their actions? (See table1.)

The score of the operational measurements are aggregated to reflect the score of each learning principle, so each learning principle has a score ranging from 0 to 2 (*guidance* can be 3). The total learning score of a game is the sum of the five learning principles, which can range from 0 to 11.

Learning Principles	Operational measurement
Situated Learning	*Story/ Background*
	Environment
Effective Social	*Reference real world*
Practice	*Hyperlink to real world information*
Identity	*Avatar*
	Character/Role
Shared Value	*Multiplayer option*
	Discussion forum
Guidance	*Tutorial/ Practice*
	Help/ Hint function
	Instant feedback (eg. Points, punishment)

Table1. Operational measurement for learning principles

Reliability and Validity

There are three coders for this study. Reliability and validity assessment were undertaken for this study's primary variables: Message structure and Learning Principles. An additional 10% of the population was sampled to test for inter-coder reliability. The simple percentage

of agreement among coders is .89 for message structures, and .93 for learning principles. Scott's Pi was .82 for message structure, and .89 for learning principles.

Results

After excluding three games which were no longer available through the links in my sampling, this study analyzed 87 environmental serious games on the internet. The findings indicated that a majority of existing serious games presented their pro-environmental message as facts but allowed certain degree of problem-solving for the learners. All the games incorporated certain amount of learning principles, and the games had an average score of 5.84 out of 11 learning principles. My hypothesis was supported as games that used more problem-based messages incorporated more learning principles than games that used fact-based messages.

This study's first research question **RQ1** asked what proportion of existing games presented their messages in problem-based messages, and what proportion in fact-based messages. Results (see Figure 1) showed that 47.13% (n=41) of games used a combination of fact-based and problem-based messages to communicate their pro-environmental values. The games usually set a pro-environmental goal for the learners, emphasizing the fact that pro-environmental actions are preferred over anti-environmental actions. But they will encourage learners to figure out how to achieve the given pro-environmental goals, usually as

a problem for learners to solve and explore. 12.64% (n=11) of the games had no instruction at all, or only had instructions on game controls. What was surprising was that even though previous researchers argued that video games would be most effective if messages were presented as problems for the learner to experience and reflect upon. The finding showed that very few (11.49%, n=10) games actually allowed learners to explore the game without directing them towards certain values. And in fact more (28.74%, n=25) games did not exert the interactive potential of video games, but instead presented their message and method as facts, leaving very little space for player exploration.

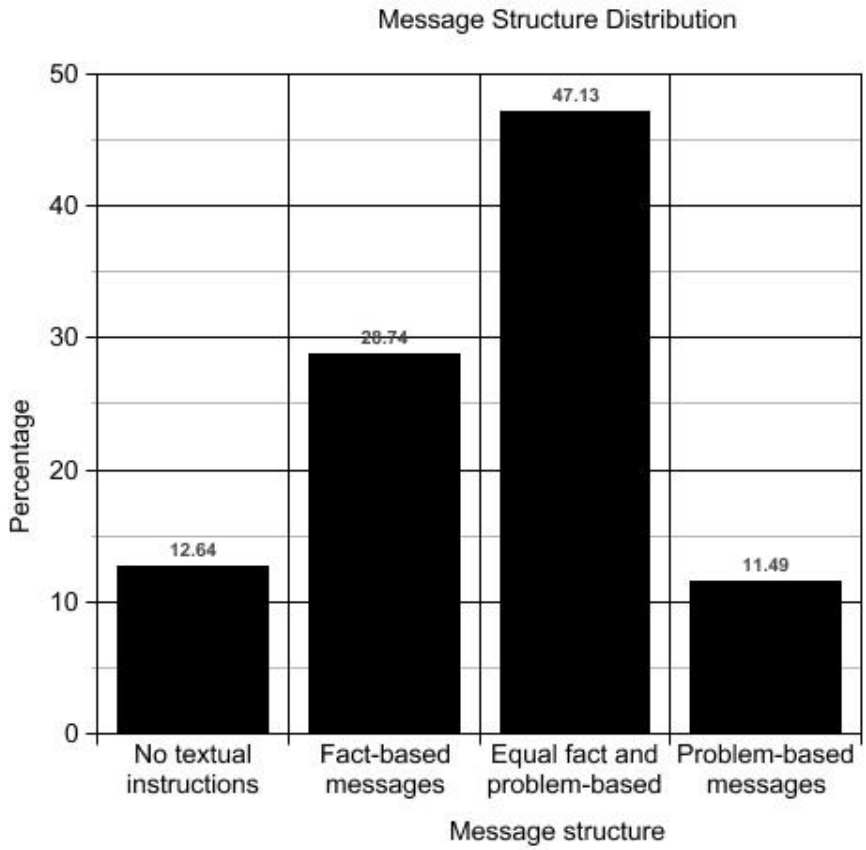

Figure 1 Message Structure Distribution

The second research question **RQ2** was what proportion of existing serious games incorporated the learning principles proposed by previous research? And how many learning principles are found in existing games? As Figure 2 shows, all the games have at least one learning principle, and more than half (59.8%) have more than five learning principles. The average amount of learning principles was 5.84 (sd=2.39).

Out of the five learning principles, situated learning and guidance had the highest means (see Table 2). The mean for situated learning was 1.56 (sd=.67), and for guidance was 1.70 (sd=.78), suggesting that most games do provide learners with a story or simulated environment to seek meanings and draw knowledge from. And the learners are guided in their experience. The games are designed to provide either tutorial to ensure that learners are prepared with basic knowledge before they proceed, or provide helping tips and instant feedbacks so the learner can immediately know the possible consequences of their actions. Shared values had the lowest mean, (0.25, sd=.49) suggesting that most games did not design factors to facilitate player interaction or communication. Maybe because this study focused on web-based serious game and not the video games designed for classroom use, it is possible that facilitating player interaction was not the major concerns of the providers.

	Situated Learning	Effective Social Practice	Identity	Shared Value	Guidance	Total Learning Principle
Mean	1.5632	.9885	1.3333	.2529	1.7011	5.8391
Std. Deviation	.67688	.84212	.78750	.48748	.77931	2.38636

Table 2 Frequency of learning principles

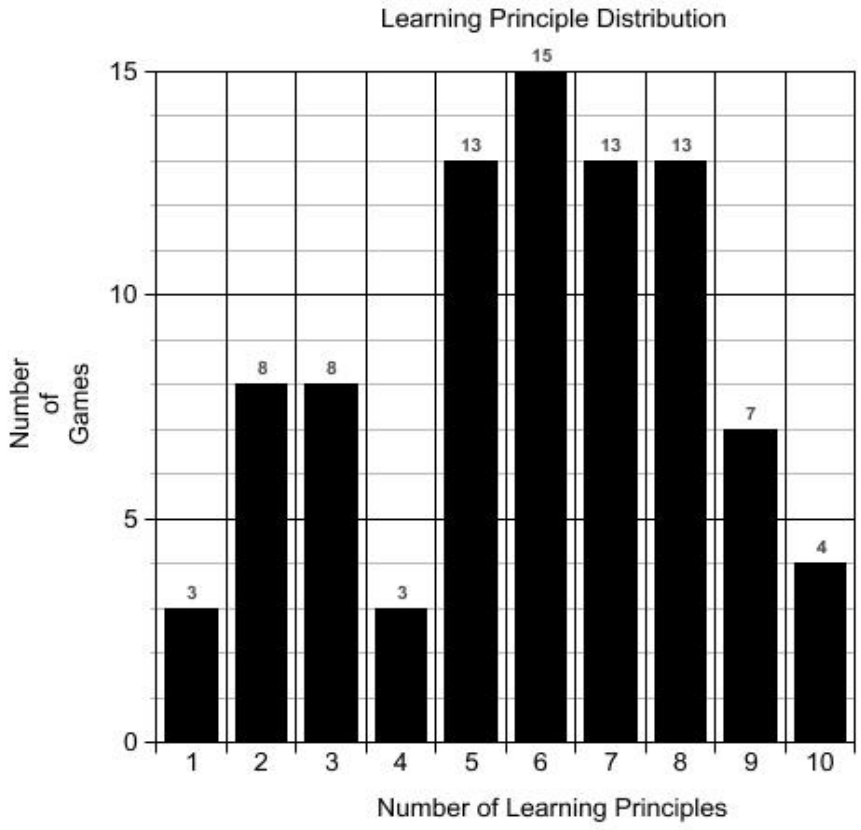

Figure 2 Learning Principles Distribution

The main hypothesis **H1** for this study is that games which use problem-based messages will have more learning principles incorporated than games which use fact-based messages.

The data was consistent to this hypothesis. As shown in Table 3, games that used problem-based messages had an average mean of 8.3 in learning principles, which is higher than those that used a mixture of fact and problem-based messages (6.07), those that used purely fact-based messages (5.80), and significantly higher than those that did not include any textual instructions (2.82). ANOVA was applied to determine whether the difference was significant, the results showed that the overall difference was significant ($F=13.83$, $p<.001$).

Post hoc comparisons using Tukey HSD test indicated that the difference between no textual instructions and any form of messages was highly significant ($p<.001$). The question is whether the three forms of messages were significantly different. The test indicated that games which used fact-based messages was not significantly different to mixed fact and problem-based messages ($p=.948$), but was significantly different to games that used problem-based messages ($p<.05$). Games that used mixed fact and problem-based messages was also significantly different to games that used problem-based messages ($p<.05$)

In other words, the results suggest that we can predict the amount of learning principles in a serious game by assessing the message structure in its introductions. Games that had no instructions had very few learning principles, and games that presented their instructions in facts had less learning principles than games that presented their instructions as problems.

Message Structure	Situated Learning	Effective Social Practice	Identity	Shared Value	Guidance	Total Learning Principle
None	.6364	.3636	.6364	.0000	1.1818	2.8182
Fact-based	1.7600	.7600	1.6800	.1200	1.4800	5.8000
Mixed	1.5854	1.2439	1.1463	.2927	1.8049	6.0732
Problem-based	2.0000	1.2000	2.0000	.7000	2.4000	8.3000
Total	1.5632	.9885	1.3333	.2529	1.7011	5.8391

Table 3 Means comparison of learning principle between message structures.

Conclusion

Through a content analysis of existing web-based serious games, this study found that most games presented their intended message through a mixture of fact and problem-based messages. The learning principles proposed by previous studies were found across all the games, and a majority of the games incorporated more than five learning principles out of 11. The most common principles were situated learning and guidance. Data in study was consistent to the hypothesis that the amount of learning principles could be predicted by assessing the message structure in game instructions.

As with any research, there are limitations to this study. First, only serious games on the internet were sampled, this study did not examine serious games that are sold and used in

classrooms. Therefore I can only generalize the implications to games that are found online. Further research is needed to know whether the serious games in the school curriculum have similar results. However, my findings implied that if parents or teachers want to find games for environmental education through the internet, they can predict the amount of learning principles through this preliminary assessment of message structure in game instructions.

Second, this study did not measure the frequency or strength of the learning principles in the games, I only assessed their presence. Therefore it is possible that a game may have very few but strong learning factors. In other words, more diverse principles may not be as important as few strong one. Further experimental research is needed to determine whether more learning principles lead to better learning effects.

Third, this study did not consider interacting effects between factors and the learner. Certain factors may interact with other factors to create strong learning effects, and certain gamers maybe affected by specific factors due to their past experience or preference. This is a limit of content analysis method, and future research is needed to test the actual effects of these learning principles on learners.

With respect to the limitations, this content analysis provides a measurement scale for assessing the educational potential of serious games from a design perspective. It also uses empirical date to confirm the relation between problem-based learning and game-based learning, emphasizing the strength of video games in its ability to present simulated

experiences for learners to solve and gain knowledge.

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