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Learning in Single- Versus Multiplayer Games: The More the Merrier?

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Abstract

From the observations of successful entertainment games, it is hypothesized that implementing a single-player option may require a different approach from that in a multiplayer option, in terms of game design. To find out whether this could be true and to understand what the specific approaches could entail for educational games, three separate yet related investigations were conducted to examine single- versus multiplayer games: an investigation of two educational games designed and evaluated by the authors, a theoretical investigation from a game and learning perspective, and an empirical investigation of 23 case studies. From these three investigations, it turned out that a "single-player approach" is data intensive, has formal rules, and uses direct transfer and individual learning. On the other hand, a "multiplayer approach" is less straightforward. From a game perspective, it can be characterized as process intensive and having social rules. When related to learning, however, it could be positioned on any dimension. This exploration shows that the approaches differ to a large extent and that designers have to find a fit between what option they choose and approach they take.

Keywords

educational games, evaluation, game attribute, game design, hypothesis building, learning, learning effectiveness, multiplayer, single-player

Today's entertainment games often offer a single- as well as a multiplayer option. In a game such as UNREAL TOURNAMENT III (2003), players can decide to battle their way through artificially intelligent bots or ask their buddies to jump in and play against

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them. It seems an unwritten rule, or one that is driven by player demands, that games should have both options. However, another trend in the entertainment industry has recently developed, one of focusing deeply on either the single- or multiplayer option. Ken Levine, lead designer of BIOSHOCK (2007), decided to not include a multiplayer option. He was convinced that focusing on the single-player experience would lead to a better game as the design team would not be distracted by a multiplayer component. Levine has been proven right, as BIOSHOCK has been announced as one of the best games of 2007. *Jolt Online Gaming* ("BIOSHOCK review," 2007) even called it the best game of the year: "it is one of the most progressive, gripping and downright fun games to hit the market in the last decade."

Another success story is the 32-player, multiplayer-only shooter WARHAWK (2007). The game does not come with a real story or any sense of why the player is fighting; it simply offers an exciting gameplay experience. Game reviewers praise the game for its balance of "tactical considerations and finger-on-the-trigger action" (Gerstmann, 2007b). An explanation for this well-balanced multiplayer experience is that the designers were not distracted by incorporating typical single-player features into the game.

The successes of BIOSHOCK and WARHAWK could be attributed to a smart distribution of resources. By focusing on a single- or multiplayer option, that particular option has become successful. Although this could be true, it is our conviction that implementing a single-player option requires a different *approach* from a multiplayer option. Another explanation of the successes, therefore, would be that the designers found a right fit between the amount of players and the eventual game.

Based on our own experience, we hypothesized that, if one is creating a successful game, the single-player or multiplayer option needs to be aligned with a specific approach, this may have far-reaching consequences for the design of *educational games*. In contrast to their entertainment counterparts, these games try to go beyond the criterion of "fun" (Harteveld, Guimarães, Mayer, & Bidarra, 2010; Sawyer, 2002). They have a certain instructional message or goal that extends further than the context of the game, such as improving an organization or teaching how to do math. This means that a "learning" criterion is equally relevant for educational games; it may also mean that the implemented approach does not only affect the entertainment value, it may influence the impact on learning as well.

To explore the game design hypothesis of the relationship of the game attribute "number of players" on learning outcomes (for a review on the relationships between game attributes and learning outcomes, see Wilson et al., 2009), we conducted three separate yet related investigations. We first looked into two educational games, LEVEE PATROLLER (2007; single player) and SIMPORT-MV2 (2007; multiplayer), which we developed ourselves ("LEVEE PATROLLER Versus SIMPORT-MV2"). In our second investigation, we looked at the subject theoretically from a game and learning perspective ("A Game Perspective" and "A Learning Perspective," respectively). Finally, we examined it empirically by drawing on the results of 23 case studies into learning effectiveness ("An Empirical Investigation"). With these three investigations, we are able to make a firmer conclusion about whether more is merrier ("Conclusions").

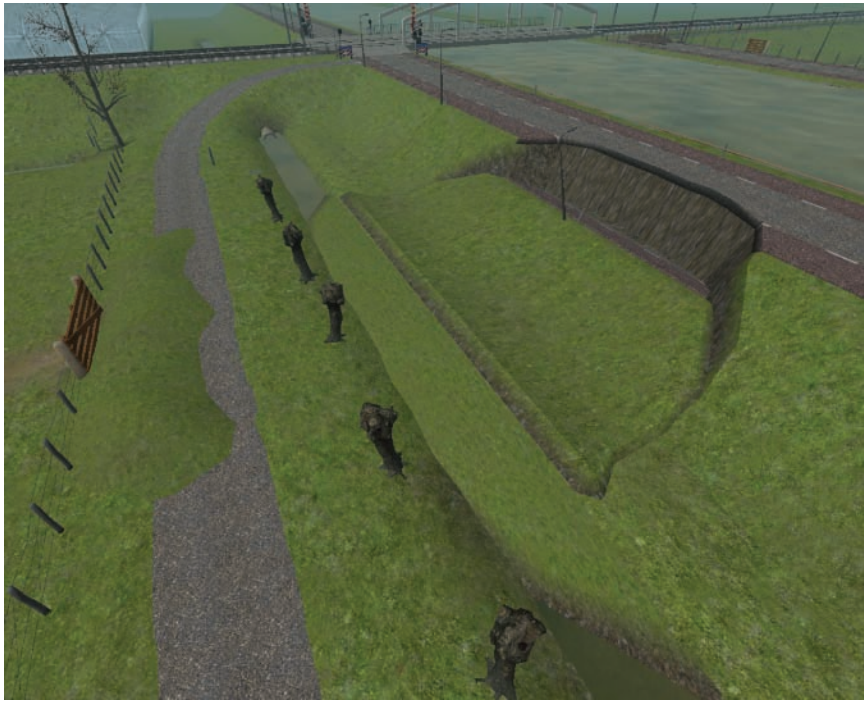

Figure 1. LEVEE PATROLLER screenshot
Note: The screenshot shows a levee failure that players need to report.

LEVEE PATROLLER Versus SIMPORT-MV2

When developing educational games, designers wonder about several options and one of these concerns is the single- versus multiplayer option. Consideration of these options does not take place to the extent that designers—including ourselves—are aware of the needs and potential effects for constructing a "good" educational game: one that achieves its learning objectives. For this reason, we started our hypothesis exploration by looking into the design and evaluation (based on observations and surveys with Likert-type scales from 1 to 5) of two educational games that we developed (see Figures 1 and 2).

The first game, LEVEE PATROLLER, intends to train levee patrollers, who are the first line of defense in preventing the adverse effects of water crises, to inspect levees (see Harteveld et al., 2010). Levees (or dikes) are the natural and artificial barriers that protect the land from flooding. The job of patrollers involves recognizing failure symptoms on time and communicating relevant findings to the central field office, which can take further action. Practicing these skills of recognition and communication is difficult in reality, as levee failures are quite rare.

Figure 2. SIMPORT-MV2 screenshot
Note: The screenshot shows a part of the port that players built

To enable patrollers to get the much-needed experience, LEVEE PATROLLER was designed. In this "single-player three-dimensional first-person" game, a player starts out in a region and has to find every failure. If a player does not find and deal correctly with a failure in time, it will lead to a levee breach that floods the whole region. The learning objectives of the game are failure recognition and procedural training. These types of knowledge and skills are standardized and very specific and have been prescripted in the game. Different players, therefore, experience largely the same sort of experience.

Early results of play sessions with 24 levee patrollers indicate that these professionals had fun ($M = 4.5$, $SD = 0.82$), perceived to have learned ($M = 4.4$, $SD = 0.66$), and would like to play the game again ($M = 4.0$, $SD = 1.00$). We also observed that the game is immersive and increases motivation. It was hard to get any attention from the players.

The second game, SIMPORT-MV2, is a computerized simulation game that mimics the real processes of the planning and exploitation of the Maasvlakte 2 (MV2) in the Port of Rotterdam (Bekebrede & Mayer, 2006). MV2 is an artificial land mass built to foresee the shortage of space that is needed for expanding the port activities in the near future. The game is played with a management team of three to six players, divided over

three roles: the general, commercial, and infrastructural director. Teams need to plan, coordinate, and implement the necessary decisions to build and exploit MV2.

The game is developed to gain insight into any unforeseen effects of one or more development strategies and design variations of MV2 in the medium term (30 years). Another objective is to stimulate multidisciplinary thinking on commercial and technical/infrastructural considerations. It is not the game's intention to tell the players the best strategy or the most desired design; instead, it is up to the players how to play it. This "open-endedness" makes SIMPORT-MV2 a game in which the process of playing and its outcomes are quite diverse and, to some extent, even unknown in advance.

Based on the evaluation of playing the game with 60 professionals, the players agreed that they enjoyed participating ($M = 4.4$, $SD = 0.62$). An important noted reason for this concerned the group process and interaction. This means that the social context contributed significantly to the players' enjoyment. Players also said they found it educative to participate ($M = 4.1$, $SD = 0.79$). They agreed that the game improved their insights on the strategic and commercial complexity of the project MV2, but interestingly enough, they also agreed that SIMPORT-MV2 can promote better communication ($M = 4.1$, $SD = 0.69$).

Although a fair comparison between both games is difficult, it is still possible to look at some of the findings of both games to get a better idea of whether a single-player option requires a different approach from a multiplayer option. For instance, both games show high scores on the fun and (perceived) learning factor. Based on this information, we can conclude that, in both instances, they have been found successful from a game and learning perspective (assuming that both factors are good representatives of both perspectives; see also Anderson & Lawton, 2009; Harteveld et al., 2010).

Yet further analysis of the two games shows that they differ widely in their design and specific outcomes. Whereas LEVEE PATROLLER teaches specific knowledge and skills in a rather closed environment, SIMPORT-MV2 is focused on broad and general insights that can be derived from an open game. It is not known beforehand how a session will evolve, whereas with LEVEE PATROLLER, it can be pointed out precisely when what will happen and what is needed from the player to perform well. Looking at the results, it we noticed that the social context of SIMPORT-MV2 has influenced how players experienced the game and what they learned. These were in addition to the learning objectives, socially oriented skills, such as communication.

Hence, from our own experience, the idea that a single-player and a multiplayer option require a different approach to create a good game is supported. This means that LEVEE PATROLLER may have adopted what we call a "single-player approach" and SIMPORT-MV2 a "multiplayer approach." To explore the hypothesis further, we subsequently looked at it theoretically from a game and learning perspective.

A Game Perspective

Strictly speaking, choosing a single- versus a multiplayer option means whether players decide to play on their own or together with friends. Quite often, this delineation becomes blurry as players could play a single-player option together with friends as well. The

main difference between the two forms of social play is rather obvious: with the multiplayer option, more than one individual interacts with the game environment, while with the single-player option, the friends interact with the player but not with the game environment. This section looks into the differences from a game perspective. Based on literature and our own experiences, we found two major differences, which we labeled "data versus process intensity" and "formal versus social rules."

Data Versus Process Intensity

The first difference between single- versus multiplayer games is that the outcomes of player versus computer interaction can be controlled to some extent by the designer, while the outcomes of player versus player are more difficult to control. The way to control for both sorts of interactions, in digital as well as analog games, is to impose rules on the player (or players; Juul, 2005; Salen & Zimmerman, 2004). In digital games, these rules are represented by scripts. Scripts connect processes, such as algorithms, equations, and branches, with data, such as data tables, images, sound, and text (Crawford, 2003). If a player, for instance, defeats a monster or pulls a switch, this constitutes a number of processes coupled with data that trigger new data, such as a new area that the player is able to enter.

If a game relies heavily on data, preconfigured elements on which the player does not have much influence, the game can be considered "data intensive" (Crawford, 2003). If, on the other hand, much of the game is dependent on a combination of rules that are largely manipulated by the player, the game becomes less linear and more procedural. In that case, it can be considered as "process intensive." Both types affect what the game offers in terms of gameplay, which is defined as the challenges that the game imposes on the player and the actions that the player has to deal with them (Rollings & Adams, 2003). For clarification, the definition of both forms is outlined briefly below.

- Data intensity = Linear preconfigured gameplay
- Process intensity = Nonlinear emergent gameplay

Both types of intensities have to be considered in developing a game. To prevent a combinatorial explosion, an overabundance of outcomes because of the many possibilities that the player may have (Rollings & Adams, 2003), designers have to look into the possible outcomes of the player's interaction with the game. Based on the type of game and the available technology, they eventually have to decide to what extent the experience becomes data or process intensive. In considering this, it matters whether the game has a single- and/or a multiplayer option, because the possible outcomes in a single-player game are less compared with a multiplayer game. The outcomes of the first depend on one variable, the player, while the outcomes of the latter depend on more than one variable (i.e., the interaction between players). This means that a data-intensive method seems more suitable for single-player games, because the outcomes of these types of games are more predictable and less diverse.

However, a number of designer tricks exist to prevent a combinatorial explosion and to combine the data-intensive with the process-intensive modules intelligently (Rollings & Adams, 2003). For instance, a designer can decide to merge all possible actions to one or two possible outcomes. The "game tree of death" in a game such as DRAGON'S LAIR, where players can only make the right decision or else die, is an example of this. Another solution is to make use of "quests." These are nested, concurrent and/or serial assignments within a game world with concrete and attainable goals, such as gathering building materials to forge a sword, as in ZELDA: THE PHANTOM HOURGLASS (2007; see also Aarseth, 2005). With a quest system, the world can be regulated in a process-intensive way, but at the moment that players accept a quest, data-intensive parts are instantiated. Such a system gives a feeling of freedom, whereas, in fact, players are still forced to play linear sequences. Popular games, such as WORLD OF WARCRAFT and GRAND THEFT AUTO IV, make use of this system.

Based on this, it is no surprise that most adventure games or role-playing games, games that rely heavily on linear sequences (i.e., narrative), tend to be single-player games. As it is already difficult to let a story unfold based on the actions of one player, for multiplayer games, the story is put to the background or is intelligently coupled to certain game elements. Basically, multiplayer games use a system that relies on nonlinear interaction (e.g., WARHAWK). In contrast, a single-player approach leaves space for connecting interaction to linear elements, such as a story or the ability to unlock new game areas (e.g., BIOSHOCK). In other words, multiplayer games tend to be more process-intensive, while single-player games tend to be more data-intensive.

If we look at LEVEE PATROLLER and SIMPORT-MV2, it can be seen that the first is much more data intensive than the second. Everything is more or less prescripted with LEVEE PATROLLER, except for the freedom that players have in walking around the three-dimensional environment. In contrast, SIMPORT-MV2 leans on a number of processes that players can influence from which the game calculates its states. This makes it rather process intensive.

Formal Versus Social Rules

Another difference between single- and multiplayer games is that the latter rely on "social rules" (or implicit rules) beside the more formal (scripted) ones (Salen & Zimmerman, 2004). In board games, this becomes very clear. It is not uncommon to notice in a game such as Monopoly (Darrow, 1935) that players combine forces to fight the player who is winning or for a player to frustrate another, because that player frustrated him or her last time. These "rules" are not written down or required to play the game. Nonetheless, they do determine how the game is played.

These types of social rules appear in digital games as well—for example, in WORLD OF WARCRAFT, a system emerged in which experienced players play together with new players. Within this construction, an implicit rule holds that the experienced player takes the loot, while the new player has the advantage of getting stronger (i.e., "levels") along the way. Players who do not abide by these social rules are considered malpractitioners

and can be banned or excluded from further play. This way, social rules are enforced by other players and can be considered as a meaningful part of the play experience.

Next to the emergence of social rules, multiplayer games contain more socially oriented goals. In these games, the goal is to cooperate to achieve something or to beat the other players, whereas in single-player games, it is more about beating the system, by getting high scores or by being faster. This social aspect in multiplayer games leads to extra motivation on behalf of the players. Malone and Lepper (1987) found this type of motivation in their analysis of the motivational factors of games and called it "interpersonal motivation." In single-player games, this pressure is of course not present, unless it is played together with friends. In that case, a similar sort of pressure could be created. Nonetheless, the presence of friends does not affect the game: it only influences the experience of play.

From this, we are able to distill two definitions that separate the formal from the social rules in games:

- Formal rules = Written configurations that are developed beforehand by the designers of the game
- Social rules = Unwritten configurations that emerge during the game and socially oriented goals that are prewritten by the designers

It seems obvious that multiplayer games are more likely to have social rules, but to many designers, its consequences on design and outcomes are not clear. We argue that it is important to take this into account, because the social dimension influences how the game is played and may give players an extra stimulation to perform well. This means that, on top of the extra difficulty to control the interaction outcomes in a multiplayer game, this option could lead to unknown ways in which the game evolves because of the emergence of social rules. In return, a multiplayer game is extra stimulating.

With SIMPORT-MV2, we noticed how rewarding the addition of extra players can be and how social rules can emerge. In this game, different groups came up with their own "rules" of how to organize and play the game. With LEVEE PATROLLER, the only social element that could be found was competitiveness among players to get the highest score.

A Learning Perspective

The teaching feature of games has led many educators to consider games as an instructional method, not only within formal education but also for organizational learning (Aldrich, 2004; Gee, 2003; Prensky, 2001). To build a game for learning, many design aspects have to be considered and the choice between a single- and a multiplayer option is one of them. Designers need to take two important notions on learning into account to make this decision. We labeled these "direct transfer versus open-ended learning" and "individual versus social learning."

Direct Transfer Versus Open-Ended Learning

In instructional design, roughly two types of learning approaches exist: direct transfer (i.e., the traditional approach) and open-ended learning (i.e., the alternative approach; Land & Hannafin, 1997). With direct transfer, it is assumed that the learner consumes the message, which has been thought of in advance by its creators. Books, lectures, and other traditional instructional methods rely on this type of learning. Less traditional methods such as games could use this too. A game designer predefines a certain message for a game, such as literacy or mathematical knowledge and skills, and hopes that the players pick up this message.

Of course, teachers, writers, and game designers do not control how their users are interpreting their messages. Users have different experiences, mental models, and so on, that influence how they convey information (Hamilton, 2005). Messages could even be misinterpreted or are unconsciously rejected, because they may not be consistent with the values and beliefs of the user. Whether a message gets across or not, the main point to be stressed is that using direct transfer learning means having specifically predefined, concrete, and measurable learning objectives that players obtain at the end of the experience.

It is a misunderstanding that direct transfer learning is equal to having a data-intensive game, although it is more likely to be data- rather than process intensive. Take for instance SEPTEMBER 12TH (2003), a toy simulation in which the player is able to bomb a Middle Eastern village with civilians and terrorists. By bombing terrorists, more terrorists appear and so it should appear to the player that it is useless to bomb terrorists. In SEPTEMBER 12TH, the message is a product of the game's rules: a clear example of how data are combined with processes to directly transfer knowledge and/or change player's attitudes toward a subject.

It is further important to note that messages do not have to be factual; they can relate to procedures, conceptual ideas, or metacognition as well (i.e., Anderson & Lawton, 2009; Salas, Rosen, Held, & Weissmuller, 2009). Similar to how this is done in SEPTEMBER 12TH, these aspects do not require to be captured in data but can be enforced by devising the right types of processes.

In contrast to direct transfer, open-ended learning does not have predefined and measurable learning goals (Land & Hannafin, 1997); it concerns itself more with getting insight into a certain topic, discussing it, or triggering people. This does not mean that open-ended learning does not have any predefined learning goals: They are just much more broadly defined and abstract.

To illustrate a game aimed at open-ended learning, look at PEACEMAKER (2007). In this game, the player chooses sides among the Israelis or Palestinians and has to create a balance between internal affairs and foreign policy. This goal of creating harmony is related yet does not reflect the actual purpose of the game, which is to get an understanding of the difficulties of the Israeli-Palestinian conflict. The game is about awareness and not so much about (directly) acquiring the knowledge and skills of becoming a political leader.

In an open-ended style of learning, it is essential to debrief players afterward so as to let them reflect about the experience. The actual learning occurs during this phase, more so, because players regularly have trouble in reflecting on their game experience while playing (Egenfeldt-Nielsen, 2005). They are either too immersed or the game is too complex for them to see the wood for the trees. While debriefing can be used for direct transfer as well, in that case, it is more to test whether the message came across rather than to elaborate about the experience.

In summary, we can roughly define direct transfer versus open-ended learning as follows:

- Direct transfer learning = Consists of specifically predefined, concrete, and easily measurable learning objectives and assumes that players have obtained these at the end of the experience
- Open-ended learning = Consists of broadly defined, abstract, and difficult-to-measure learning objectives and assumes no particular results at the end of an experience but, rather, some insights that have been obtained

Relating these concepts to a single- versus a multiplayer game, it becomes clear that it is more difficult to use direct transfer learning in a multiplayer game. It is not impossible, but because the game experience in a multiplayer game is much more emergent and unexpected, the value of direct transfer might diminish depending on how the game develops. Direct transfer, as a concept, therefore, seems to be more suitable within a single-player game context. On the other hand, for open-ended learning, a multiplayer game seems more suited to achieving valuable discussions and insights because of its greater dynamic and nonlinear gameplay. This is consistent with how LEVEE PATROLLER, which uses direct transfer in explaining to players how failures look and how to report them, and SIMPORT-MV2, which gives some insight and feeling with how ports are developed and exploited and therefore applies an open-ended learning style, are developed.

Individual Versus Social Learning

Within the large bulk of learning literature, there has always been a debate over the extent to which learning is socially grounded. Although human beings are individuals who process information on their own, they are, at the same time, influenced by others, as humans tend to imitate and are part of multiple groups or communities of practice from which they derive their identities, values, and beliefs (Wenger, 1998). If learning is a social process, it would seem better to implement such social learning processes within a game environment. Obviously, a multiplayer game is more suitable to achieve this than a single-player one.

Another reason to opt for a multiplayer game from a social learning perspective is that “two people know more than one” and “the whole is more than the sum of its parts” (Senge, 1990). With this, we refer to the common knowledge that a group of people are able to know and reach more than a single individual. On the other hand, in experiments,

it is also been proven that groups show an average performance, that not everybody within a group contributes just as much, and that some people do not contribute at all (Forsyth, 2006). What if we were able to make all individuals the best people in class through a single-player game? We would certainly know who is slacking and who is not in that case.

On top of this, although learning is social in many of its aspects, when participants show a wrong set of skills and/or knowledge, putting these people together will not necessarily create a strong learning experience. They may stick to their old habits or worse, learn the wrong type of behavior. To isolate individuals from each other and train them individually might, for this reason, be a much more controlled and preferable way of teaching.

Of course, the choice between a single-player and multiplayer game is not that clear-cut at all; it depends on the setting and use of the game but above all on what type of learning goals it has. For instance, more socially oriented learning goals, such as teaching "communication skills," are probably better off by using a multiplayer game. On the other hand, narrowly and specifically defined skills, such as addition and subtraction, would be a better fit within a single-player game.

The main aspects for designers to consider are the extent to which they want (a) to control the learning experience and (b) to make the learning content socially oriented. The more socially oriented it is, the better a multiplayer game seems to be (see Thavikulwat, 2009). Maybe the designer wants to modulate the difficulty for actors to cooperate or communicate. This is an inherently social problem and difficult to implement by using a single-player game. Another key design aspect is the ways in which social influences within the game process lead to stronger or weaker learning experiences. Groups may, for example, encourage or frustrate a learning process. Finally, designers should not forget that using single-player games in a group environment may also encourage social learning. Scaffolding, imitating, and other types of social learning could take place, although these principles can also to some extent be implemented in a game by guiding players by nonplayer characters.

Based on this, we can see that the difference between individual and social learning relies on the learning *content* of the game and on the *process* of acquiring the learning objectives of the game. Both sides are included in the definitions below:

- Individual learning = Consists of most learning content, such as knowledge (e.g., facts, understandings, and procedures), cognitive skills (e.g., reasoning, memorization, and planning), and attitudes (i.e., a person's disposition toward an object). As a process, individual learning takes place without others.
- Social learning = Takes place with others. It is strongly oriented toward interpersonal skills, such as communication, collaboration, or negotiation.

From the above, social learning seems rather limited. Despite this, it needs to be emphasized that by learning in a social context many individually oriented learning goals can be achieved. Conversely, with nonplayer characters, socially oriented learning goals

can be reached in a single-player environment. Thus, no binary opposition exists between the two. Cross-fertilization is possible. In fact, a reason why many business schools apply multiplayer games is that much business-related knowledge and skills are best learned when engaged in a social context (Thavikulwat, 2009). This can also be seen in SIMPORT-MV2, in which an understanding of unforeseen effects and multidisciplinary thinking is achieved in a social context. This means that while the processes strictly differ between single- and multiplayer games, the content can be mixed. For LEVEE PATROLLER, however, all of the learning was individually oriented.

An Empirical Investigation

From our theoretical exploration, we are able to conclude that, if a single- and multiplayer educational game requires a different approach, the first would be characterized by being data intensive, relying on only formal rules, using direct transfer learning, and focusing foremost on individual learning. Conversely, the second would be characterized by being process intensive, relying on both formal and social rules, using open-ended learning, and focusing foremost on social learning. These outcomes are congruent with our observations in the first investigation, in which we compared LEVEE PATROLLER and SIMPORT-MV2.

To strengthen or falsify our hypothesis further, we expanded our research to a third investigation. For this investigation, we searched for evaluation studies into the learning effectiveness of games. In our search, we found Ke's (2009) meta-analysis of the findings of educational games to be most useful. In this section, we describe the method, analysis, and results of this empirical investigation.

Method

Based on 256 studies on educational games, Ke (2009) selected 89 for his meta-analysis of games as learning tools. The other 167 studies were excluded, because they were about other effects than learning, about development, about theoretical propositions, or about conceptual analysis. Because the aim of our empirical investigation was to find other empirical case studies with an emphasis on learning effects and relate these to the theoretical dimensions that we derived from the game and learning perspective, we used this selection of 89 studies as a starting point for our analysis.

We reduced this sample for several reasons. First, cases that did not deal with the effectiveness of the game but, rather, with an exploration of it in terms of design or gender effects were excluded. Second, a number of studies did not specify what sort of learning (e.g., knowledge, skills, or attitudes) occurred or did not specify whether it concerned a single- or multiplayer game, which made their conclusions rather pointless for our aims. A third and final reason for exclusion concerned the sample size of the study. These varied from 3 to more than 3,000. We selected the studies with a sample size more than 30, to exclude the most unreliable outcomes but keep enough studies for an analysis. In the end, the initial set of 89 studies was reduced to 23 relevant studies.

For each of the remaining case studies, we tried first to determine the game and learning characteristics. We considered whether the evaluated game used:

- a single-player (SP) or multiplayer (MP) option
- data- or process intensity
- formal and/or social rules;
- direct or open-ended learning
- individual or social learning

Apart from the above categorization, we categorized the outcomes as well. Based on a primary investigation of the results, we were able to sort the outcomes into six rough categories:

- Increase in attitude (A): Players changed their disposition or behavior toward a certain object after playing the game.
- Increase in cognitive skills (C): Players improved intellectual abilities such as reasoning, memorization, and planning.
- Increase in interpersonal skills (I): Players improved on socially oriented skills, such as communication, collaboration, and negotiation.
- Increase in knowledge (K): Players gained facts, procedures, concepts, and understandings after playing the game.
- Increase in motivation (M): Players were more enthusiastic or willing to engage with the subject matter.
- No significant effect (N): The study showed no improvement on any of its objectives.

Our procedure, after categorizing the different case studies on game and learning characteristics and outcomes, was to recognize certain patterns. Based on these patterns, we were able to see to what extent they relate to our findings from theory and our observations with LEVEE PATROLLER and SIMPORT-MV2.

Analysis

Table 1 presents our categorization of the 23 case studies for single-player games; Table 2 does this for the multiplayer games. From both tables, we can first of all observe that most of the evaluated games are single-player games (17 out of 23). We found only six multiplayer games in total. Assuming the sample is representative, an explanation of the asymmetric division could be that it is easier to design and measure the effect of a single-player educational game.

Another significant pattern that emerged from the data concerned what we have termed the *single-player approach*: 14 out of the 17 single-player games are data intensive, use solely formal rules, and apply direct transfer and individual learning. Most of the learning outcomes of these games were related to an increase of cognitive skills (C)

Table 1. A Categorization of the Single-Player Case Studies

Study	Data Versus Process	Formal Versus Social	Direct versus Open-Ended	Individual Versus Social	Findings
Bartholomew et al. (2000)	Data	Formal	Direct	Individual	C
Cahill (1995)	Data	Formal	Direct	Individual	A
Goodman, Bradley, Paras, Williamson, and Bizzochi (2006)	Data	Formal	Direct	Individual	K
Gopher, Weil, and Bareket (1994)	Data	Formal	Direct	Individual	C
Johnson (1993)	Data	Formal	Direct	Individual	K
Noble, Best, Sidwell, and Strang (2000)	Data	Formal	Direct	Individual	K
Okolo (1992)	Data	Formal	Direct	Individual	N
Oyen and Bebko (1996)	Data	Formal	Direct	Individual	N
Paperny and Starn (1989)	Data	Formal	Direct	Individual	K/A
Perzov and Kozminsky (1989)	Data	Formal	Direct	Individual	N
Ravenscroft and Matheson (2002)	Data	Formal	Direct	Individual	K
Ricci, Salas, and Cannon-Bowers (1996)	Data	Formal	Direct	Individual	M
Rosas et al. (2003)	Data	Formal	Direct	Individual	N/M
Yip and Kwan (2006)	Data	Formal	Direct	Individual	C
Squire and Barab (2004)	Process	Formal	Direct	Individual	K
Ke and Grabowski (2007)	Data	Social	Direct	Individual + social	C
Renaud and Suissa (1989)	Data	Social	Direct	Individual	A

Note: A = increase in attitude; C = increase in cognitive skills; K = increase in knowledge; M = increase in motivation; N = no significant effect.

and knowledge (K). Interestingly enough, the 4 out of the 23 studies that did not show a significant effect at all were part of this group as well. Although this argues against our hypothesis, many other variables influence the learning outcomes aside from a fit between the amount of players and its further approach, such as the quality of the design in general, the methodology to study the results, and the fit with the game and the context in which it is played and by whom. Nevertheless, these results do show that using a single-player approach is not a guarantee for success.

From the single-player exceptions, one study (Squire, Barnett, Grant, & Higginbotham, 2004) that used a single-player game with a process-oriented design was found. This study concluded that participants increased their knowledge (K). The two other studies included social rules in their design. One of them (Ke & Grabowski, 2007) also employed social as well as individual learning, while the other (Renaud & Suissa, 1989) used only individual learning. The measured effects of both were an increase in cognitive skills and a change in attitude, respectively.

When we look at the six multiplayer games, all of them employ social rules. This is not very surprising given the nature of multiplayer games. Five of these six are also

Table 2. A Categorization of the Multiplayer Case Studies

Study	Data Versus Process	Formal Versus Social	Direct Versus Open-Ended	Individual Versus Social	Findings
Doyle and Brown (2000)	Process	Social	Open-ended	Social	C
Gremmen and Potters (1997)	Process	Social	Direct	Social	K
Kashibuchi and Sakamoto (2001)	Process	Social	Direct + open-ended	Individual	C
Thomas and Cahill (1997)	Data	Social	Direct	Individual + social	K/A
Washbush and Gosen (2001)	Process	Social	Open-ended	Individual	I
Wildman and Reeves (1996)	Process	Social	Open-ended	Individual + social	I

Note: A = increase in attitude, C = increase in cognitive skills, I = increase in interpersonal skills, K = increase in knowledge.

process oriented. However, of these five, only three use open-ended learning and only one focuses particularly on social learning content (Doyle & Brown, 2000). This means that the "multiplayer approach" is much less visible. Even though the number of multiplayer games is much lower than the number of single-player games, we can clearly see that these types of games are much more "schizophrenic" than single-player games. This is confirmed when we look at the learning outcomes, which range from attitudes (A), cognitive skills (C), interpersonal skills (I), to knowledge (K). Basically, every study but two (Washbush & Gosen, 2001; Wildman & Reeves, 1996) has a different outcome.

Results

From the empirical analysis, it is possible to identify a number of important conclusions:

- A correlation was found between single-player games and a single-player approach.
- A correlation was found between multiplayer games and two characteristics of the multiplayer approach: process intensity and social rules.
- No correlation exists between multiplayer games and the other two characteristics of the multiplayer approach: open-ended learning and a focus on social learning.

These conclusions show that, while single-player games can be considered archetypical, multiplayer games cannot, except for their process intensity and their inclusion of social rules. Based on these data, it was impossible to conclude what type of approach

is better to employ and under which circumstances, but it can be noticed that designers—whether or not they are conscious of it—already seem to use a single-player approach when it comes to the single-player option. Largely, they do this with success, because most studies indicated an increase in knowledge and skills. These observations, therefore, support our hypothesis of the single-player approach.

On the other hand, the results do not support the hypothesis of the multiplayer approach. Although it can be seen that multiplayer games are different in terms of their design, in terms of learning they can be comparable with what the single-player games try to achieve. This means that we need to rephrase the multiplayer approach to one that is process intensive, uses social rules, and applies direct transfer, open-ended, individual, and/or social learning. Multiplayer games are thus multiheaded tools that can, apparently, touch on many areas of learning. Nevertheless, it remains to be seen whether multiplayer games are just as effective in certain areas of learning as single-player games.

This empirical exploration has several limitations. In the first place, we make many assumptions about the case studies: we assume, for instance, that their results are reliable and valid. Moreover, we were limited by what the original researchers of these studies measured. It could very well be that the games affected other areas of learning as well. This could, for example, mean that only the knowledge of players of a multiplayer game are measured, while at the same time they may have gained many interpersonal skills. Most important, we were very restricted by the documentation of the researchers of their games; it proved to be quite difficult to retrieve from the descriptions what their game was about and how we could possibly categorize it. Although the original researchers of course did not have our theoretical framework in mind when writing their article, it does indicate that game researchers need to be more precise in the future in describing their games. Otherwise, it becomes difficult to appreciate the results of games (and possibly replicate this with another but similar game) when the underlying logic of the games is unclear.

Conclusion

From the observations of successful entertainment games, it is hypothesized that implementing a single-player option may require a different approach from a multiplayer option. If, in creating a successful game, the single- or multiplayer option needs to be aligned with a specific approach, this may have far-reaching consequences for educational games: games that need to be fun as well instructional. This hypothesis is first supported with our observations of LEVEE PATROLLER and SIMPORT-MV2. It turns out that both educational games differ on a number of characteristics. After that, we explored the difference theoretically. From this, a framework was retrieved with four dimensions on which both types of options can be placed on opposite ends. The dimensions are data- versus process intensity, formal versus social rules, direct transfer versus open-ended learning, and individual- versus social learning. These findings are congruent with our earlier observations of LEVEE PATROLLER and SIMPORT-MV2.

Our third investigation, an analysis of 23 case studies, supports the hypothesis that a single-player approach can be characterized as being data intensive, having solely formal rules, and using direct transfer and individual learning as well. Based on this, it can be concluded that a single-player approach is a better fit if a game is used for transferring a specific or standard set of knowledge and skills.

In contrast, from our observations with our games and our theoretical investigation, we expected that a multiplayer approach can be characterized as being process intensive, having formal as well as social rules, and using open-ended and social learning. Based on this, we could have concluded that a multiplayer approach concerns a better fit if broad and abstract insights need to be derived or if the learning objectives are socially oriented. However, the empirical case studies show that this is not that straightforward. While multiplayer games are, indeed, process intensive and use social rules, they are applied for direct transfer, open-ended, individual, and/or social learning. Although it is unclear how well they perform on each type of learning in comparison with a single-player approach, these results suggest that a multiplayer approach can be seen as being fit for multiple learning objectives.

While successful exceptions to these characterizations may exist and the context in which the game is used matters as well, these notions are useful for educational game designers to keep in mind. It shows that, while in certain situations the more may be the merrier, in others it may not be. Designers should be aware of this.

Nevertheless, more thorough research that focuses on the specific game attribute of the "number of players" is needed to prove the above-mentioned claims (see also Wilson et al., 2009). Specifically, more elaborate case studies with rigorous methods that investigate the design and outcomes of single- versus multiplayer games in an educational setting are needed. This is, moreover, needed as literature about this subject is, currently, incredibly sparse. In fact, when it concerns research, we can say confidently that the more is the merrier.

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