5.13 Defining Learning Space in a Serious Game in Terms of Operative and Resultant Actions

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Abstract. This paper explores the distinction between operative and resultant actions in games, and proposes that the learning space created by a serious game is a function of these actions. Further, it suggests a possible relationship between these actions and the forms of cognitive load imposed upon the game player. Association of specific types of cognitive load with respective forms of actions in game mechanics also presents some heuristics for integrating learning content into serious games. Research indicates that different balances of these types of actions are more suitable for novice or experienced learners. By examining these relationships, we can develop a few basic principles of game design which have an increased potential to promote positive learning outcomes.

1.0 INTRODUCTION

In his book, *What Video Games Have to Teach Us About Learning and Literacy*, J. P. Gee alludes to the concept of a learning space while describing the creation of an educational *psychosocial moratorium* within serious games:

> *"…I learned that video games create what the psychologist Eric Erikson has called a psychosocial moratorium – that is, a learning space in which the learner can take risks where real-world consequences are lowered* [1]*."*

While Gee does not expound further on the concept, the phrase "learning space" may be inferred to mean the world created by the video game. When a learner engages with the game world, they do so with few of the risks that might be inherent in performing similar activities in the real world.

For the purposes of closely examining or creating a learning space, it can be helpful to examine this concept further. In doing so, we might discriminate more strictly between the game environment and the learning space. A learning space is likely to not include everything that constitutes the game. The learning content may be restricted to only certain subset of the mental space defined by the game, with other portions of the game having little or no bearing on the intended instruction. Based on this paradigm, a serious game designer should consider how the distinction between learning space and non-learning space impacts learning outcomes, and accordingly, where the learning content belongs in the game.

Insight into these questions can be found in an examination of player actions within games. J. Schell describes a design model which distinguishes between the types of actions that a player has available to them. This categorization of actions can be used to characterizing the depth, complexity and elegance of the game. By moderating the ratios of action types, the game designer can create distinct experiences for the player. Similarly, an instructional designer might engage in the same sort of moderation, not only in developing player actions, but additionally in deciding which types of actions will reflect the learning content.

The combinations of actions and learning content also bear on the cognitive load induced upon the learner. Research by Park, et al, and Lee et al, demonstrates a relationship between interaction levels, learner proficiency levels, and learning outcomes [2, 3]. By carefully constructing the actions available to the user, a designer has a set of tools though which it may be possible to create serious games that achieve desired pedagogical outcomes.

2.0 DISCUSSION

2.1 Games, Learning Spaces, and Learning Content

Simple observation seems to indicate that in most cases, the learning content in serious games does not make up the entirety of the experience. Games are likely to include aspects which are not related to the instructional material. This can be seen most readily when the motif of a game, as defined by C. Totten [4], is not specifically dictated by or dependent upon the learning content. Totten distinguishes between the mechanics and the motif of a game, with motif comprising aspects of the game like narrative and themes. Motif is the aesthetic or thematic presentation of the game beyond the mechanics which embed the rules. Hunicke, et al. similarly associate game aesthetics with the emotional "fun" response evoked by the player interacting with the game [5].

In the business model simulation game *Lemonade Stand*, shown in Fig. 1, the distinction between aspects of the motif and the learning content are clearly visible [6]. The game is intended to teach about the challenges of running a business, but the aesthetics of dogs, cats, and strange creatures have no bearing upon that content.

Even while serious game developers and researchers stress the importance of integration of game fantasy and learning content, there is still evidence that the motif and mechanics do not entirely overlap with the learning content.

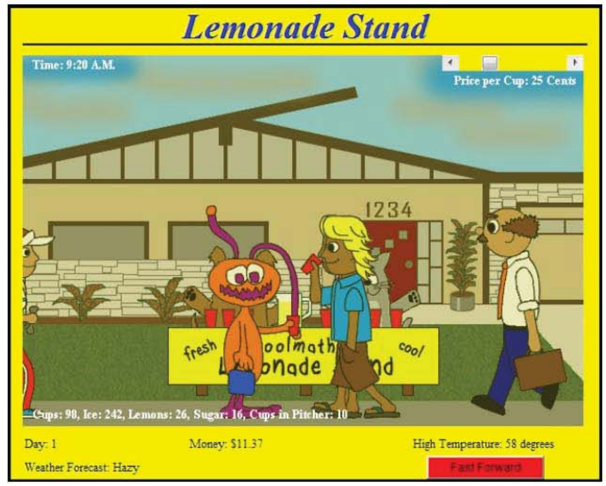

Fig. 1. Lemonade Stand business simulation game depicting the distinction between the game and the learning content [6]. The learning content is focused on the challenges of purchasing good and making a profit, and have nothing to do with the animals and strange creatures shown in the screenshot.

M. Habgood, et al. created a game to teach division skills and demonstrated the importance of endogenous fantasy in which the fantasy of the game is intrinsic to the learning content and vice versa. Yet a screen shot of the game still shows that it is challenging to not include aesthetic content in a game that is not necessarily related to the learning content [8]. Figure 2 shows Habgood's Zombie Division game, in which the learner must use numerically oriented weapons to "divide" the enemy skeletons.

Even though the game is cited as an example of intrinsic fantasy, it is clear to see that the motif is not directly relevant to mathematical division. The aesthetics of the game depict a small Greek warrior attacking skeletons, and the linkage between these fantasy characters and division is created through the mechanics of the game, not the motif.

Fig. 2. Screenshot of Zombie Division, in which the learner controls a Greek Warrior and uses the principles of division to defeat skeleton opponents [7]. As with Lemonade Stand, the aesthetics or motif of the game have almost no connection to the learning content.

Based on these examples, it may be concluded that the learning space is a subset of the larger game environment, and that further, the learning space is a result of the interaction of learning content with the game elements (mechanics and motif). In part, the learning content may be presented in the game or simulation through expository methods, such as narratives, cut scenes, or non-interactive demonstrations. But the learning space which the game users actively explore is created when the learning content is made available to the user through game-play. It is through these mechanics that the user has a chance to meaningfully interact with the content. Figure 3 depicts the relationship between Game, Learning Content, and Learning Space. The next challenge is to understand how designers create game-play for the users.

2.2 Operative and Resultant Actions

In *The Art of Game Design*, Schell discusses two important concepts which play a significant role in shaping game mechanics. These concepts are the users operative and resultant actions [9].

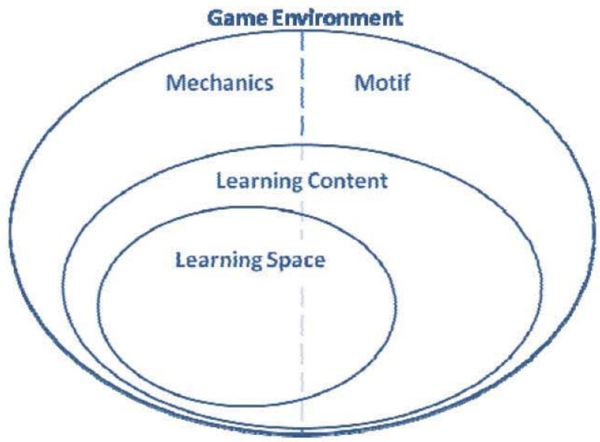

Fig. 3. The relationship between Game Environment, Learning Content, and Learning Space. It is likely that Learning Space derives primarily from Mechanics side of the Game Environment, but the it is possible to derive portions of it, as well, from the Motif.

Operative actions are the basic actions which a player might engage in. In a game of checkers, these operative actions might include moving a checker forward, jumping an opponent, or moving a king backwards. Due to the nature of computers, video games must explicitly delineate these actions and their effects. As a result, in computer games, these actions tend to be very discrete and well defined.

Resultant actions, on the other hand, are the “meta” actions which the player can take in order to achieve a goal. In the example of checkers, the player might force an opponent to make an unwanted jump, or protect a piece from being taken. Both of these resultant actions might take the form of the same operative action (moving a checker forward), but they serve different purposes, and are enacted for different reasons. Schell describes how these resultant actions are often not concrete parts of the game, but rather are aspects which develop though game play. As such, they are ill-defined, and more subjective than operative actions. To an extent, these resultant actions are analogous to strategies developed to achieve goals within the game. Even in games implemented on video games, which tend to require stricter definition due to the nature of computer programs, these actions have a larger degree of latitude than their operative counterparts.

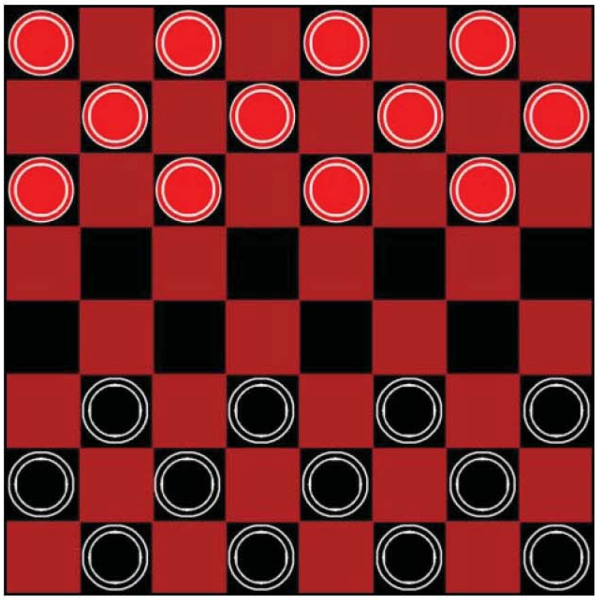

Fig. 4. Checkers Board. Each piece only provides the player with a few operative actions, but the game still has many resultant actions.

Schell also discusses the interaction of operative and resultant actions, and their effect upon the complexity and the potential for emergence in a game. From this discussion, it is possible to discern some basic formulae with which to characterize the games in terms of complexity, elegance and depth. The following are proposed definitions of these terms, in the context of Schell's actions.

Complexity may be thought of as a reflection of the operative actions. Games are complex when the user has many specified actions they can take. A game of chess, for example, is a relatively more complex game than checkers. The chess player has many operative actions; each side consists of sixteen pieces, made up of six unique types. These unique types each behave differently, providing the player with distinct operative actions for each piece on the chess board. In contrast, as mentioned above, checkers has fewer operative actions for the player to consider.

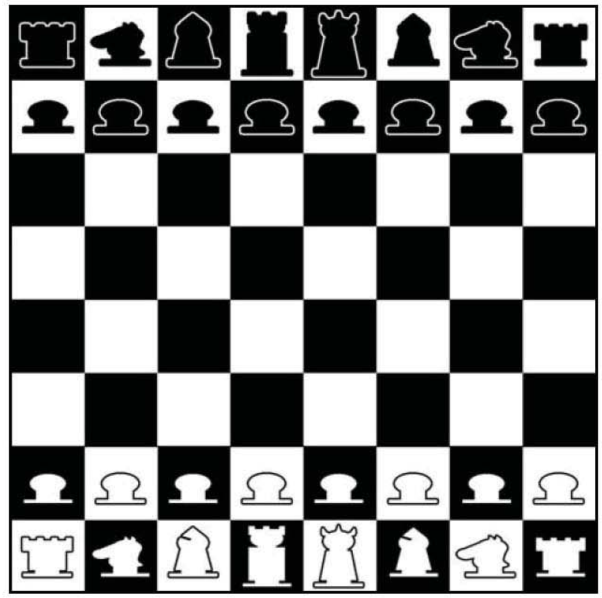

Fig. 5. Chess Board. Each type of piece has unique rules that govern it's movement, effectively giving the player a larger number of operative actions than Checkers.

Elegance, on the other hand, can be considered the ratio of resultant actions to operative actions. Games that are elegant have more resultant actions in comparison to the number of operative actions. The game of Go is a good illustration of elegance. Go only has two operative actions – to place a stone on the board, or to pass. All stones are identical, and behave the same, and the action of placing the stones is the same every time. However, Go, like Chess, still has an abundance of resultant actions.

That abundance of resultant actions sums up the last characterization: depth. Schell suggests that one way to create the potential for resultant actions through the addition of clever and interactive operative actions.

However, he simultaneously cautions that too many poorly considered operative actions can result in a game that is "bloated, confusing, and inelegant" [9]. Games which are elegant achieve depth while keeping complexity to a minimum.

From the Instructional Design perspective, Morrison, et al. provide specific prescriptions for designing instruction based on the type of learning content [10]. In examining these prescriptions, it seems likely that it is in the depth of the game, rather than the complexity of the game, that the user might engage in activities that would support teaching principles, rules, and procedures. In contrast, if the learning content is limited to facts and concepts, requiring lower levels of Bloom's Taxonomy [11], then it may be sufficient to embed the learning content into the operative actions, or even in the game motif.

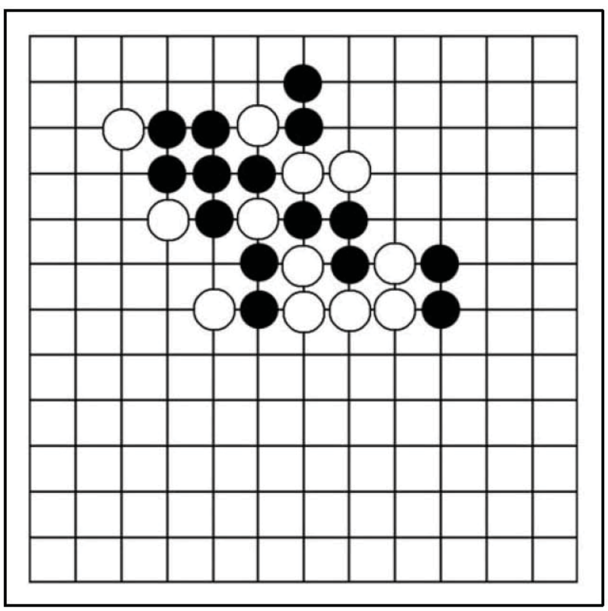

Fig. 6. Go board. With only two operative actions, the game of Go still manages to create a very deep game play experience, embodying the notion of elegance.

Schell's operative and resultant actions provide the serious game designer with a means by which to instill desired levels of complexity and depth into a game. By manipulating these elements of the game design, game developers can attune their game design to support instructional needs. But the potential pedagogical implications for operative and resultant actions are even farther reaching.

2.3 Actions and Learner experience Levels

The balance between operative and resultant actions may have bearing not only on the learning space created and the elegance of the game, but may also on the type of learner for which the game is designed.

S. Park, et al. studied the use of simulations with high and low levels of interactivity by experienced and novice learners [2]. One conclusion drawn was that experienced learners did better with more complex simulations, while inexperienced learners performed relatively worse. Within the Park's research, the difference in the complexity of the simulations can be largely described as a difference in the amount of operative actions given to the users. The results of their research also indicate that the mean cognitive load score for inexperienced students increased along with the increase in complexity, while the mean score for experienced students decreased. Figure 7 shows the results from Park, et al.'s research.

Based on this research, it would follow that advanced learners would benefit more for having many operative actions though which to interact with their serious games. Designers targeting such learners would be free to include many operative actions, presumably creating both complexity and depth. In contrast, serious games designed for novice learners should focus on elegance, reducing the number of operative actions in order to reduce the complexity of the game interactions.

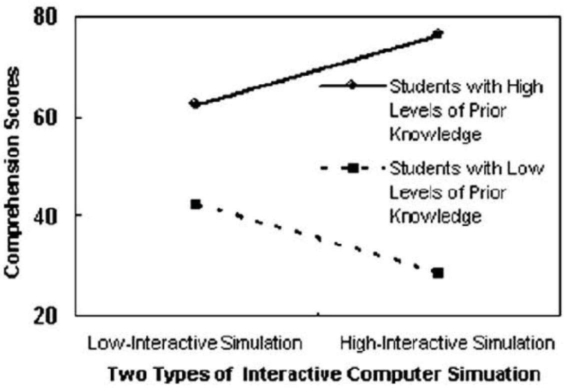

Fig. 7. Results of Experiments conducted by Park, et al. Students with high levels of prior knowledge performed better with high-interaction (and therefore higher complexity) simulations than those with low levels of prior knowledge.

2.4 Learning Curves

The results of Park, et al.'s research bear a remarkable resemblance to the hypothetical learning curve suggested by S. Alessi [12]. Figure 8 depicts Alessi's curve. Park's graph only presents 4 data points, making it difficult to ascertain whether the data fully describes the curve, but experimental results seem to support the hypothetical curve.

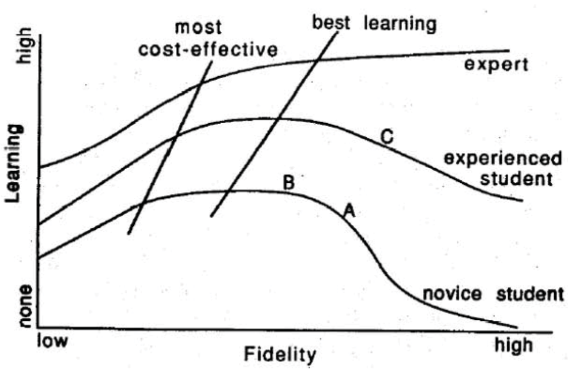

Fig. 8. Alessi's Hypothesized Learning Curve. Alessi proposes that more experienced students will benefit from higher fidelity simulations, while the performance of novice students will decline after reaching a certain optimal level.

Alessi's curve is hypothetical, and his article concludes by stating that future research should assess what aspects of a simulation should be varied and under what conditions this variation should occur. Park's data suggests that interactivity is one place in which variation should occur, and Schell's actions further suggest that manipulating the operative actions made available to a learner may be a good prescription for calibrating a game to the needs of the learner.

It should be noted that Alessi is comparing learning to simulation fidelity, while Park, et. al. are describing learning (as reflected by comprehension scores) against the levels of interactivity in the simulation. In order to make the leap between the two graphs, it must be presumed that interactivity is correlated with simulation fidelity.

2.5 Cognitive load

The justification for making this leap between interactivity and simulation fidelity may be found in J. Sweller's definition of cognitive load, and it's three components: intrinsic, extraneous, and germane load [13].

Intrinsic cognitive load results from the difficulty of the material being dealt with. Extrinsic cognitive load is created by the manner in which the material is presented, and lastly, germane cognitive load is the load associated with processing and encoding schemas. Alessi defined fidelity as the degree to which a simulation reflects reality, or the phenomena being presented in the instructional content [12]. Park's presentation of simulation complexity via interactivity is a clear reflection of the intrinsic load being imposed on the learner [2]. Based on these definitions, simulation fidelity correlates to the intrinsic cognitive load, while simulation or game interactivity correlates to extrinsic cognitive load.

Complexity and fidelity form two sides of the cognitive load triumvirate, and experimentation by Lee, et al. concludes that adjustments of presentation (and corresponding intrinsic load) can be used to calibrate the overall cognitive load [3]. Additionally, their experimental results are similar to those of Park, et al., though their experimental design included an additional factor comparing iconic versus symbolic representation. Increasing or decreasing the extraneous cognitive load presented to the learner can compensate for their experience level with the learning content. If the learner is experienced, then they can be effective with complex presentations, whereas novice learners should be given more simple interfaces in order to account for their position on the learning curve with respect to the intrinsic difficulty of the subject matter. As before, the moderation of the extraneous cognitive load can be performed by adding or removing operative actions.

3.0 CONCLUSION

This paper has presented a discussion of the nature of conceptual learning spaces within in serious games. By examining selected research and theoretic constructs, it may be possible to enact specific game design principles to elicit desired learning outcomes. Specifically, this paper proposes that:

- Learning spaces are not synonymous with game environments, but rather are a subset of learning content, which in turn, is a subset of the game environment.
- Learning spaces are functions of the interaction of the learning content with the game mechanics and with the game motif.
- Fact and concept categories of learning content may be taught through learning spaces based primarily on operative actions and motif within games.
- Rule, principle and procedure categories of learning content may be taught through learning spaces based primarily on resultant actions within games.
- Novice learners may be better served with lower complexity games with fewer operative actions.
- Learners of increasing experience may benefit more from added operative actions.

While these conclusions are based on existing research and experimentation, there is a need to confirm these propositions with additional causal studies. Much of what is proposed here is based on small leaps of knowledge that could benefit greatly from relevant empirical data.

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