

Examining the Predictors of Moderating Student's Achievement from Game-Based Learning Studies

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Abstract

Game-based learning (GBL) is increasingly being applied in education. However, few studies have examined its theoretical bases. One exception is the exploratory work conducted by Kebritchi and Hirumi (2008). For extending their work, this study first categorized four major isms that might serve as pedagogical theoretical bases: behaviorism, cognitivism, humanism, and constructivism. Based on this foundation, the study applied meta-analytic methodology to present the findings quantitatively using GBL-related documents such as articles. Through the meta-analytic processes, the study presented an important contribution by examining the articles that contain predictors that moderate achievement. In sum, this study can extend research issues related to the pedagogical theoretical bases of the GBL.

Keywords: *game-based learning, pedagogical issue, learning theory, meta-analysis.*

Introduction

Game-based learning (GBL) has recently become more popular and has become a focus of attention in the field of education (Hong et al. 2009; Pivec 2007). Most studies investigating the effectiveness of using games for learning have reported positive outcomes. McFarlane et al. (2002) found that GBL is not only able to benefit students' personal and social development, but can also improve their language,

literacy, mathematical, and physical development, as well as their creativity. Research conducted by de Lisi and Wolford (2002) supported their findings, suggesting that use of games in learning environments is becoming an increasingly relevant trend (Moreno-Ger et al. 2008).

The importance of theoretical bases for the GBL

Despite these very positive findings, few studies have conducted in-depth investigations of the pedagogy behind GBL. More importantly, little has been done to synthesize information about how an established theoretical base is applied during the design of educational games (Kebritchi & Hirumi 2008; Kiili 2005). Therefore, Kebritchi and Hirumi (2008) conducted pioneering research about the pedagogy behind modern educational computer games and provided valuable results based on 50 articles and 55 educational games. For example, after contacting the game designers, Kebritchi and Hirumi found that only 22 games were based on established learning theories.

The major isms of learning theories

To clarify how mainstream games can support learning, we extended Kebritchi and Hirumi (2008) research to additional classification and generalization of learning theories. After conducting a literature review, we differentiated learning theories chronologically and identified four major isms: behaviorism, cognitivism, humanism, and constructivism (Amstutz 1999; Conole et al. 2004; Guy 1999; Jarvis et al. 2003; Kirriemuir & McFarlane 2004; Merriam 2001). The first ism, behaviorism, involves learning theories of direct instruction, programmed instruction, and social learning theory. The second ism, cognitivism, involves learning theories of attribution theory, elaboration theory, cognitive development theory, and conditions of learning. The third ism, humanism, involves learning theories such as experiential learning. Finally, the fourth ism, constructivism, involves learning theories of social development theory, case-based learning, cognitive apprenticeship, discovery learning, problem-based learning, situated learning theory, and actor-network theory.

The purpose of this study

Regarding the GBL issue, a theoretical base is crucial. With the exception of the exploratory research conducted by Kebritchi and Hirumi (2008), few studies have investigated the pedagogical foundation in this field. Hence, this study tried to apply a meta-analysis methodology to assess the pedagogical theoretical bases of the GBL

and to extend the findings produced by Kebritchi and Hirumi. Specifically, this study examined a crucial research question: What affects student achievement and what predictors moderate achievement through the GBL, based on articles containing pedagogy?

Methodology

This meta-analysis quantitatively integrated how the GBL affects student's achievement. The process involved the following procedures: definition of the GBL, data sources and search strategies, inclusion/exclusion criteria, coding, data-analysis, effect size calculations, and multiple regression model testing. Due to the limitation of number of pages, this study only depicts the part of inclusion/exclusion criteria. To be included in this meta-analysis, a study had to meet the major inclusion/exclusion criteria as below:

- (a) It had to involve GBL theories as a primary condition, including behaviorism, cognitivism, constructivism, and humanism. We established specific criteria to differentiate among these isms and its' representative learning theories.
- (b) It had to be publicly available or archived.
- (c) It must have been published or presented no later than October 2009.
- (d) It had to include an identifiable level of learner. All levels of learners (kindergarten to adulthood, informal schooling, or professional training) were admissible.
- (e) It had to involve situations in which students learned using computers.
- (f) It had to be of acceptable quality; only studies with no severe methodological flaws were included.

We excluded any studies that:

- (a) Had insufficient data for effect size calculations (e.g., with means but no standard deviations, inferential statistics, or sample size).
- (b) Involved simulations not used for educational purposes.

Results and Discussions

This study examined the predictors that moderate student's achievement in the GBL articles containing pedagogy. Hence, we conducted a multiple regression analysis with all predictors using SPSS to estimate the unique variance for each variable and overall variance based on a model using all predictors. Table 1 presents

the results, which can shed light on student motivation and achievement with regard to the GBL. Due to a multi-collinearity problem, three predictors were deleted from the model: participant unknown, curriculum in humanities and arts, and game type/simulation. Table 1 lists all predictors; the following predictors had significant effects on the effectiveness of GBL when the game was based on pedagogy: game design by authors, game design (other), participants being junior high school students, participants being adults, and a strategy-type game.

Together, the model accounted for 77.0% of the total variance, indicating that this model provides a good explanation of the effectiveness of GBL when the game is based on pedagogy.

Table 1. Results of multiple regression analysis.

Predictors	Standard β	<i>t</i> -value	<i>p</i> -value
Year of publication	.84	1.84	.07
Game design by authors	-1.17	-6.03	.00 ***
Game design by other	-.44	-2.86	.01 **
Participants - elementary school students	-.01	-.04	.97
Participants - junior high school students	.42	4.68	.00 ***
Participants - senior high school students	-.07	-.50	.62
Participants - adults	.67	4.00	.00 ***
Curriculum - social sciences	.87	1.49	.14
Curriculum - natural sciences	.00	.01	.99
Game type - strategy	-.46	-2.75	.01 **
Game type - board game	-.16	-1.50	.14
Game type - other	-.37	-1.20	.24

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, β = regression coefficient.

Based on above results, we have two findings that need to further discuss as below.

- *Articles about the social sciences had small t-values, and articles about the natural sciences had limited t-values*

Van Sickle (1986) reported a small effect size for social science simulations using meta-analysis procedures. This finding is consistent with results published by Randel et al. (1992), which indicated that games used in the social sciences were less

certain than those used in technical fields. However, our results indicated that games used in the natural sciences also had limited t-values, indicating a limited effectiveness of the GBL used in the natural sciences. Given the fact that games invoked different learning styles and preferences by gender, this result should be examined in more detail. Features of games should also be examined. Malone (1981) found that elementary school children prefer games with goals, computer scoring, audio effects, and unpredictability and games in which the speed of an answer affects results. Future studies should investigate students' learning styles, preferences, gender, and features of games when analyzing the effectiveness of GBL.

- *Multiple regression results differed between adult and elementary school participants*

The multiple regression results revealed that t-values were higher for adult participants ($t(11) = 4.00$, $p < 0.001$) than for elementary school students ($t(11) = -0.04$); this might be influenced by the motivation of elementary students. Kulik et al. (1985) confirmed a positive effect on achievement among elementary school pupils, but they focused on computer-assisted instruction rather than on instructional computer games. Elementary students might be drawn in by a game not because of its educational merits, but for the entertainment it provides. In contrast, adult learners tend to be more motivated than elementary school students in present study, so their achievement and motivation might be better than that of elementary school students when games are used as teaching tools.

Conclusion

For extending the research about the pedagogical theoretical bases of learning theory in the GBL studies, this study identified four major isms of learning theory: behaviorism, cognitivism, humanism, and constructivism. Based on this base, this study used meta-analysis methodology to conduct a quantitative analysis of documents related to the GBL. By integrating the pedagogical theoretical bases of the four major isms of learning theory with this quantitative meta-analysis methodology, we can extend the research about the pedagogical theoretical bases of the GBL. This study makes an important contribution to this field and suggests the directions of future research, as described below.

With regard to effect size and multiple regression, this study identified a total of 64 motivation and achievement outcomes and a small but significantly positive effect

of the GBL. Moreover, we identified five major predictors of positive outcomes from the GBL: year of publication, game design, participants, curriculum, and game type. Of these predictors, curriculum and participants were investigated in additional detail, and the participant group was clearly proven to have a significant influence on effectiveness. However, it is difficult to explain how the other predictors such as game design affect effectiveness. One reason for this difficulty is the small number of studies that fit the criteria (articles containing pedagogy and statistical results); the sample include only 15 such articles. Finally, we suggest further research should expand the sample size and then reexamine these predictors.

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References

- Amstutz D. D. (1999) Adult Learning: Moving Toward More Inclusive Theories and Practices. *New Directions for Adult and Continuing Education* **82**, 19-32.
- Conole G., Dyke M., Oliver M., & Seale J. (2004) Mapping pedagogy and tools for effective learning design. *Computers & Education* **43**, 17-33.
- de Lisi R., & Wolford J. L. (2002) Improving Children's Mental Rotation Accuracy with Computer Game Playing. *The Journal of Genetic Psychology* **163**, 272-282.
- Guy T. C. (1999) Providing Culturally Relevant Adult Education: A Challenge for the Twenty-First Century. *New Directions for Adult and Continuing Education* **82**, 19-24.
- Hong J.-C., Cheng C.-L., Hwang M.-Y., Lee C.-K., & Chang H.-Y. (2009) Assessing the educational values of digital games. *Journal of Computer Assisted Learning* **25**, 423-437.
- Jarvis P., Holford J., & Griffin C. (2003) *The theory & practice of learning (2nd)*. London: Kogan Page.
- Kebritchi M., & Hirumi A. (2008) Examining the pedagogical foundations of modern educational computer games. *Computers & Education* **51**, 1729-1743.
- Kiili K. (2005) Game-based learning: Towards an experiential gaming model. *Internet and Higher Education* **8**, 13-24.

- Kirriemuir J. & McFarlane A. (2004) *Literature review in games and learning*. Bristol, England : Bristol University Press.
- Kulik J.A., Kulik C.-L. & Bangert-Drowns R. L. (1985) Effectiveness of computer-based education in elementary schools. *Computers in Human Behavior* **1**, 59-74.
- Malone T.W. (1981) What makes computer games fun? *Byte* **6**, 258-277.
- McFarlane A., Sparrowhawk A., & Heald Y. (2002) *Report on the educational use of games*. Available at: <http://www.teem.org.uk/> (last accessed 19 September 2009).
- Merriam S. B. (2001) Andragogy and Self-Directed Learning: Pillars of Adult Learning Theory. *New Directions for Adult and Continuing Education* **89**, 3-13.
- Moreno-Ger P., Burgos D., Marítnez-Ortiz I., Sierra J. L.,& Fernández-Manjón B. (2008) Educational game design for online education. *Computers in Human Behavior* **24**, 2530-2540.
- Pivec M. (2007) Editorial: Play and Learn: potentials of game-based learning. *British Journal of Educational Technology* **38**, 387-393.
- Randel J. M., Morris B.A., Wetzel C.D, & Whitehill B. V. (1992) The effectiveness of games for educational purposes: A review of recent research. *Simulation & Gaming* **23**, 261-276.
- Van Sickle R. L. (1986) A quantitative review of research on instructional simulation gaming: A twenty-year perspective. *Theory and Research in Social Education* **14**, 245-264.