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Creating Adaptive e-Learning Board Games for School Settings Using the ELG Environment

Symeon Retalis
(Piraeus University of Educational Technology and Digital Systems, Greece
retal@unipi.gr)

Abstract: The use of digital games in education is well documented in the literature. They have been used in preschool, K-12, the university. A specific type of digital games is board games. Adding board games to the educational process can lead to an interactive stimulating learning experience. With a board game, players often learn from one another while at the same time having fun in a competitive environment. In this paper we propose the "ELG" game, an e-learning board game that adopts the basic elements of a racing board game but fosters students' creativity, problem-solving skills, and imagination as students are trying to reach the end by improving their performance in a variety of learning activities. The innovative feature of the ELG is that it offers an adaptive authoring tool that enables teachers to customize their games according to the needs, interests and motives of students. The teacher enters hierarchically categorized learning activities according to the learning goals of a course, sets the rules and assesses the learning progress easily and simply. Students participate in a discovery or exploration trying to reach the goals. After attaining them their level of activities is upgraded and they are challenged to reach the next learning goal. The dice in ELG is not randomized but controlled by the teachers in order that they can customize adaptive learning rules. The educational benefits of exploiting ELG in the learning process is that the teacher can define the levels of difficulty according to the students' needs and interests, facilitate and monitor the learning rate of each student, combine a variety of evaluation techniques, and address potential learning problems in a timely manner.

Keywords: Adaptive environments, Authoring tools, E-Learning, Game based learning
Categories: L.2.0, L.2.1, L.2.2, L.3.0, L.3.4, L.5.1.

1 Board Games in the Educational Process

The use of games in education is well documented in the literature (Prensky, 2001; Prensky, 2006). They have been used in preschool, K-12 and universities (Tanner and Lindquist, 1998; Bailey, Hsu, and DiCarlo, 1999; Games-to-Teach Team, 2003; Kiili, 2004; Gee, 2005; Burgos et al., 2007). One particular category of games is "board games". A board game is played by multiple players who move pieces across a premarked surface using counters or dice. Adding board games to the educational process can lead to an interactive learning experience (Helliar et al., 2000). With a board game, players often learn from one another while at the same time having fun in a competitive environment. It is also believed that students have a unique and fun opportunity to evaluate their own level of learning by identifying concepts not yet mastered while playing (Massey, Brown and Johnston, 2005; Hoffjan 2005).

The added value of games has been very accurately stated by Marc Prensky (2006):

- Games are a form of fun. That gives us enjoyment and pleasure.
- Games are form of play. That gives us intense and passionate involvement.
- Games have rules. That gives us structure.
- Games have goals. That gives us motivation.
- Games are interactive. That gives us doing.
- Games are adaptive. That gives us flow.
- Games have win states. That gives us ego gratification.
- Games have conflict/competition/challenge/opposition. That gives us adrenaline.
- Games have problem solving. That sparks our creativity and learning.
- Games have interaction among peers. That gives us social groups.
- Games have representation and story. That gives us emotion.

The current challenge for designers of educational games is to find ways to fuse educational content with the gameplay, so that students can solve authentic problems, engage in meaningful scientific, mathematic, or engineering practices, think creatively within these domains, and communicate their ideas expressively (Salen and Zimmerman, 2003). Thus the scope of this paper is to present the ELG, an authoring environment for creating and instantiating e-learning board games. Thus ELG is both a design and a runtime environment for learning board games.

The innovative feature of the ELG is that it offers an adaptive authoring tool that enables teacher to customize the game according to the needs, interests and motives of students. The teacher enters hierarchically categorized learning activities according to the learning goals of a course, sets the rules and assesses the learning progress easily and simply. Students participate in a discovery or exploration trying to reach the goals. After attaining them their level of activities is upgraded and they are challenged to reach the next learning goal. The dice in ELG is not randomized but controlled by the teacher in order that they can customize adaptive learning rules. The educational benefits of exploiting ELG in the learning process is that teachers can define the levels of difficulty according to students' needs and interests, facilitate and monitor the learning progress of each student, combine a variety of assessment techniques, and timely address potential learning problems. The structure of the paper is the following: in the next section we will present the main features of the ELG authoring environment that enables teachers to design an e-learning board game. Then we will present the ELG's architectural design in order to better illustrate how students learn while playing in an adaptive environment. Finally, we will present the main findings from a brief evaluation study that we performed with teachers who tried to design e-learning board games using ELG. The paper will end with a brief discussion about the main future research and development plans.

2 Designing Games with ELG

Eric Zimmerman (2006) rightly pointed out that "Everyone – both developers and educators – forgets this one: making games is really hard." [http://www.ericzimmerman.com/texts/learningtoplay.htm]. It is even harder for teachers who have basic computer skills and prefer spending their valuable time on

creating learning material rather than writing scripts in programming language for creating a board game.

Although there are plenty of ready-made educational board games, to our knowledge there is no authoring environment for creating them in an easy and user friendly way. The ELG comes to fill this gap. ELG offers a user friendly authoring environment which allows a teacher to easily and quickly create an adaptive e-learning board game re-using learning objects, such as images, questions, self-assessment or inquiry-based learning activities. ELG is also designed to offer a run time environment that allows multiple users (i.e. learners) to play an e-learning board game and collaborate while trying to solve a given learning problem. It also allows the teacher to monitor the learning process and give feedback or advice to learners when necessary. A screen shot of an e-learning board game which runs within the ELG run-time environment is shown in Figure 1. It is an adaptation of the well known board game "Snakes & Ladders".

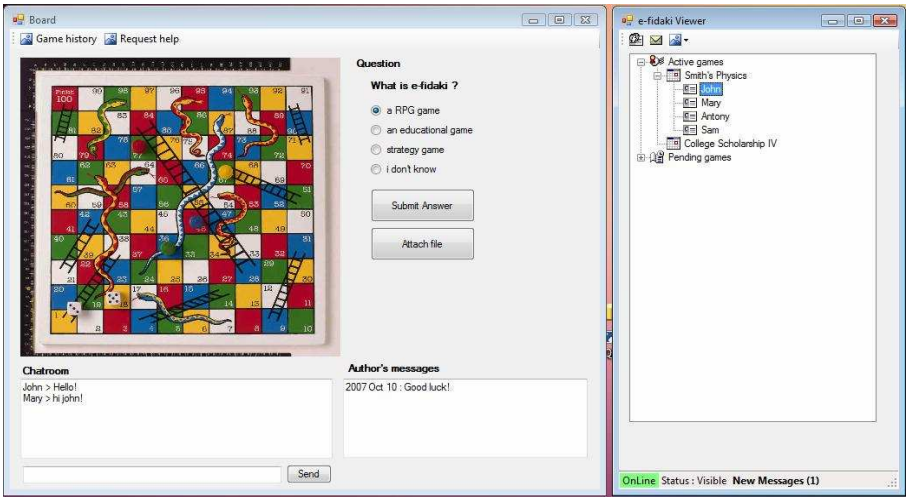

Figure 1: A screen shot of the ELG run-time environment

Today's board games should consist of colourful playing spaces rather than a classic grid of squares. Thus, it is important to allow a teacher-creator to customise the board according to his/her preferences, i.e. specifying the number of cells and adding any image that he/she likes on each cell or the background image that seems appropriate. ELG allows a teacher to do all these.

Moreover, an e-learning board game requires players to answer questions, some times arranged in a hierarchy ranging from most difficult questions to questions of intermediate difficulty, and then to questions of least difficulty. The players take turns by rolling the dice in their attempts to correctly answer the questions written on the question cards. The particular question card selected by each player as a result of his or her playing piece landing on a respective playing space corresponds to the question category for that question card set. It is the intent of each of the participants (i.e. the learners) in the game to be the first player to reach a specific end space located within

the playing course and to correctly answer the question or questions on a question card selected from a predetermined question category.

With the ELG authoring environment, the teacher can specify the main elements of a board game, which are: i) the "board", i.e. the playing space; ii) the learning activities that will be presented to learners through the question cards, iii) the dice and iv) the rules that make a game adaptive. The ELG e-learning board game development process is shown in Figure 2.

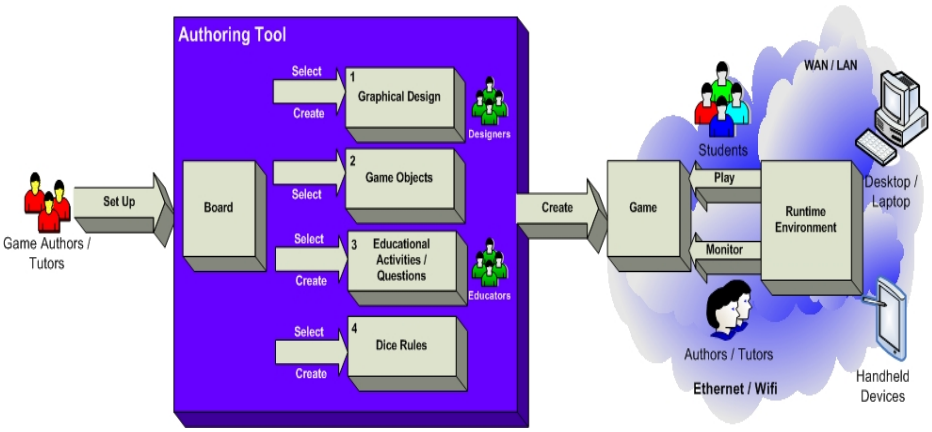

Figure 2: The ELG e-learning board game development process

Figure 3 shows a screen shot of the ELG authoring tool where the teacher adds meta-data for the game, i.e. title, course subject, educational level, etc.

Figure 3: Screen shot of the first step for creating an e-learning board game in ELG

3 Creating and Re-using Learning Activities

Students perform learning activities utilizing their knowledge and skills while a teacher is a facilitator of the learning process who intervenes when appropriate. A learning activity can be a close-type self-assessment item in the form of a multiple choice question, true-false, etc. It can also be an open-type assessment item where the student has to write a brief paragraph or create and submit a concept map, etc. The open assessment items are being assessed by the teacher while the close-type ones are automatically being assessed by the ELG runtime engine. The duration of a game can be more than a typical teaching session. Students can continue to play the game either at home or the next school days. A screen shot of the ELG authoring environment which allows a teacher to create new questions or search for existing ones is shown in Figure 4.

Each activity can be rated by the teacher as easy, intermediate or demanding according to its difficulty level. It can also be annotated according to a predefined set of categories, e.g. sports, literature and geography. The rating and annotation features allow the teacher to create a board game which could be adapted to the knowledge level and interests of the students. Moreover, the teacher can specify the feedback comments or the hints that will be shown to a student when he/she gives wrong answers to a given learning activity. For example, a teacher can allow the student to try again after having studied some online material.

The descriptive elements of the ELG activities are quite similar to the ones described in [Carro et al., 02]. Thus, an activity can be described by its *name*, its *type* ("multiple choice", "open question", "submission of a concept map", etc.), *learning goals per concept (*e.g. on the concept of "fractions", one learning goal is "Compare and order fractions"), *category* (sports, geography, etc), *difficulty level* (easy/intermediate/demanding).

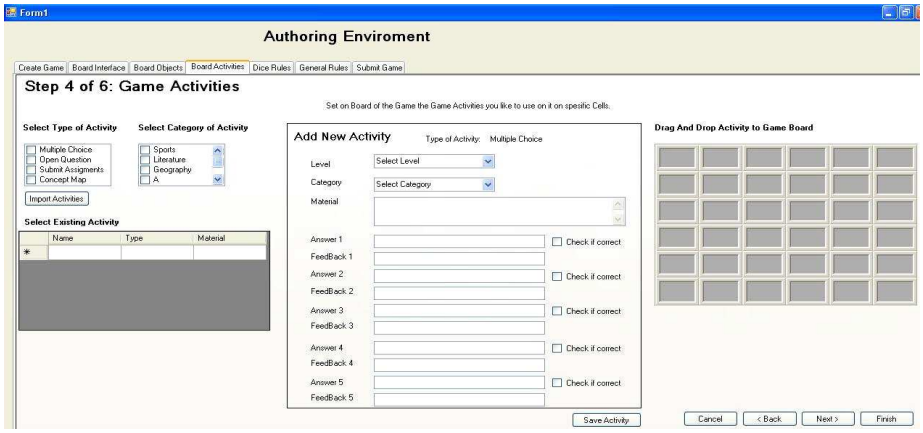

Figure 4: Creating Learning Activities via the ELG

Another innovation of the ELG is that the activities of a game are codified using the IMS QTI specification (IMS QTI, 2006) thus enabling ELG to interoperate with other IMS QTI compatible quiz tools. Thus a teacher could search at a repository with question items for adopting ready made questions to the game under development.

4 Adding Adaptivity

As already mentioned, the ELG allows teachers to add adaptivity into a game. In order to achieve adaptivity, the following elements are stored for each student:

a. *Student's Knowledge level*: Each student can be characterised as novice, intermediate or expert on a specific concept. The knowledge level is calculated at specific thresholds. For example if the score of a learner is greater than 85% at a specific activity or a set of activities then the student's knowledge level can be updated accordingly, e.g. change from novice to intermediate. As a result, the student will be asked to answer to questions of higher difficulty level.
b. *Student's interests:* information about the preferred categories of learning activities (sports, geography, literature, etc.). Having known the student's interests, the students will be called to answer questions that match his/her interests. For example, in the domain of maths, the math problem/activity that the student will be called to perform should be related to the student's favourite sport.
c. *Activity data per Student*: information like the questions that were tried, their difficulty, the hints used, etc.

Adaptivity can occur both when players are ahead (i.e. finding the game easy) and when they are behind (i.e. finding the game hard.) For example, when a player-student is behind the ELG could make navigation easier by decreasing the student's knowledge level and by giving the player more "power-ups," i.e. offering the player easier questions. When a player is doing well, and the game is becoming too easy, the ELG could automatically increase the student's knowledge level and offer the student more challenging learning activities.

The dice could also become a mechanism for adding customised adaptive learning rules. Apart from the usual randomised roll of the dice, the teacher could add the following rules (e.g. see Figure 5):

d. If a student has performed very well to a given activity (or set of activities), the dice could be "fixed" so that a player can roll high numbers. Thus, the teacher rewards the excellent performance.
e. On the contrary, if a student fails to solve a challenging activity or her learning scores are not very high, the dice could be "fixed" so that the student will roll low numbers.
f. Depending on a student's performance to one question or a set of questions, the dice could be "fixed" so that the player goes to special tiles on the board that could allow him to play once more or jump to other tiles.

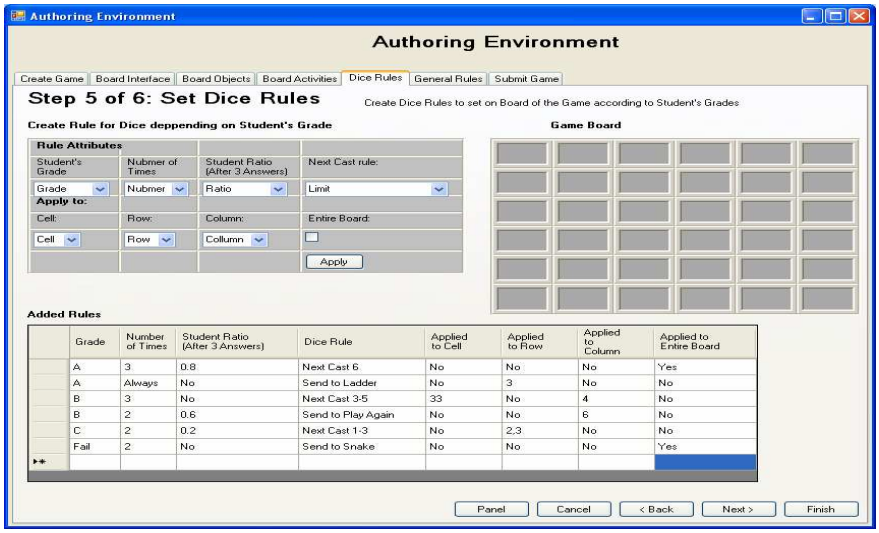

Figure 5: Adding Rules to an e-learning board game via the ELG

5 ELG architectural design details

The architectural decisions, which have been made when designing the ELG, allow students to play an e-learning board game almost anywhere and at any time. Learners and teachers may interact with each other through desktop-laptop PC's or PDA's and access the server side through Wifi or Ethernet protocols, while they are connected to LAN or WAN network. As shown in Figure 6, the main components of the ELG are: a Web server and an SQL server where data of the learning process (answers, scores, adaptive rules, students' profiles, etc.) are stored. During the execution of the game participants can exchange information -such as activity results or ideas about the problem solution- through a Mail and/or Media Server.

ELG relies on the latest web technology structures, offering a user friendly authoring environment combined with a powerful runtime engine implemented in Visual Basic .NET programming paradigm. It also takes advantage of the IIS mail server and Microsoft's media server in order to facilitate the communication between learners and teachers. For the graphical user interface Ajax technology has been exploited.

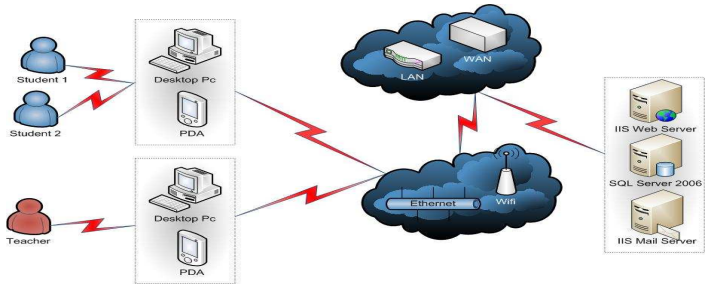

Figure 6: High level architectural deployment diagram of the ELG environment

6 Evaluation of the ELG

We performed a short term evaluation study with three school teachers. The main focus was on examining the ELG's added value from the teachers' point of view. At first, the ELG authoring capabilities and features were explained and exhibited to three (3) experienced in instructional design as well as motivated teachers (two from primary and one from secondary education) who have basic computer skills. The teachers had not any experience from using or designing educational games. All of them came from different schools and they wanted to try ELG at different subjects. Then we asked them to create independently a board game on a subject matter of their choice. Our main intention was to observe how usable teachers found the ELG authoring environment and how easy was to create add adaptation rules in their games.

It was extremely interesting and highly encouraging to find out that the three teachers developed challenging e-learning board games which had been comprised of various questions/learning activities of high quality. One teacher proposed a game for students of 7-9 years old. Her course concerned Mathematics in primary school and more specifically addition and subtraction with numbers from 1.000 to 10.000. Thus a game with learning activities about nutrients and calories in Mediterranean food was created. Another teacher tried to create an online version of the well known game about the European Union (original title: "L' Europe sur un plateau") scripted by Madeleine Deny.

The third teacher created a game that can be played at the new archaeological museum of Acropolis in Greece with the use of PDAs. As shown in Figure 7, she used the architectural blueprint of the museum as the background image of the playing space. She also designed learning activities which were related to each room of the museum. The students could give answers to either close-type questions or to open-type questions which required from the students to identify an object that holds specific characteristics (e.g. belongs to a specific period) and send its picture via an MMS.

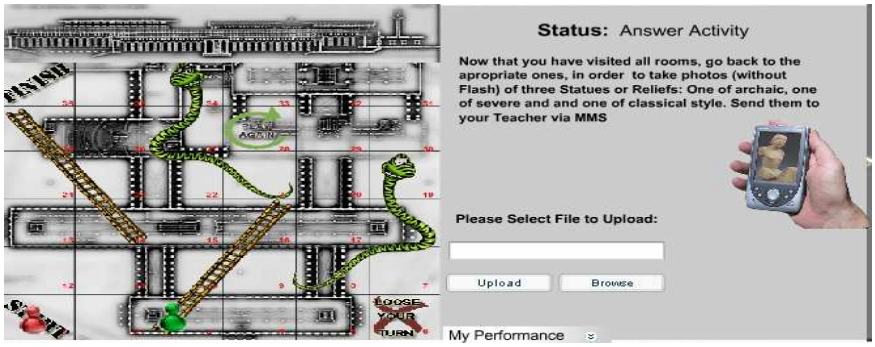

Figure 7: Example of a learning activity of a game which can be played outdoors, e.g. at the Acropolis archeological museum, with the use of PDAs

Moreover, we performed focus group interviews with the three teachers in order to gather their opinions about the usability of the ELG authoring environment. Each teacher explained to the other teachers the game and the rules that had been created. Teachers spent time on discussing about the types of the learning activities that had been designed for the needs of the games as well as the various rules that had been integrated into the games. There rules did not differ much. This is due to the fact that the teacher had been guided by the ELG authoring tool when creating them. When asked if they wanted more flexibility in creating other rules, the teachers answered that it was very helpful that they had been guided by the ELG's templates of rules for the needs of this step. On the contrary the types of learning activities, especially the open learning activities, that had been proposed differ a lot. This was inevitable since the educational level as well as the learning objectives of each game had been different.

After this first round of exchanging ideas about the games developed, teachers had been asked to comment on the usability of the ELG environment. Although there is no consensus on the heuristic criteria for evaluating the usability of educational game environments, Malone's (1992) heuristics seem to be the dominant ones. Thus we asked the teachers to express their opinion about

1. Content/Storytelling - The educational objective and content should be clearly stated in the game.
2. Interface Representations - A good game should map the learning activities to the interface actions and the learning concepts to interface objects.
3. Interactivity - A good game will always have gaming interactions that facilitate the mastery of the objective.
4. Challenge - A challenging game must have, as a goal, attainment which is uncertain and it should be personally meaningful and obvious or easily generated.
5. Feedback - Prompt feedback and rewards about the player's performance and progression should be provided.
6. Curiosity - A good game should have an optimal level of informational complexity. In other words, it should be novel and surprising but not completely incomprehensible.

7. Control - The game should offer a great deal of control to the player.
8. Mechanisms - Mechanisms for correcting errors and improving performance should be provided in the game.

This short evaluation revealed that the ELG authoring environment is usable because it grants teachers with freedom to apply their own creativity and teaching philosophy. Teachers could easily create games that could enable players to perform challenging learning activities which are associated with the objectives of the national curriculum. They believed that it was very easy to build a board game with an interesting and intuitive graphical user interface that allows players to proceed through the game smoothly. They also considered as very important the fact that they could customize and combine adaptive rules thus creating a challenging game. Although the idea of "fixing the dice" seemed very good, it was not clear to the teachers how to explain it to their students. Teachers mentioned that it is easy to predict how students would react when finding out that the game may be "fixed".

Teachers also appreciated that an ELG game can offer a great deal of control to the players who can also get prompt feedback from the teacher (or the game itself) when performing activities either alone or in collaboration with other fellow students. Finally, reusability of learning activities was considered a very important feature of the ELG authoring environment although they did not re-use any ready-made activity.

Of course, more exhaustive evaluation experiments in authentic classroom environments are needed to measure the quality of the board games that can be created via the ELG environment as well as to identify design and development weaknesses of the adaptation mechanisms.

7 Conclusions

Learning games, if used correctly, have the potential to add value to the traditional classroom-based instructional practices (Rotter, 2004; Van Eck, 2006). That is why it is so important that teachers have usable authoring tools to develop and deploy games. In this paper we presented the ELG which allows the teacher to easily create e-learning board games. Although there are very few board game authoring tools like the "Board Boss" by 5th Tradition Software, Inc., ELG is innovative because it allows teachers to easily create elearning board games. Since there is a genuine demand for personalization and scaffolding in e-learning systems (Cristea, 2007; Carro et al., 2004), adding adaptive features via usable mechanisms to board games similar to Trivial Pursuit, Monopoly, or Life can make the learning process highly stimulating. The ELG is at a beta version which allowed us to evaluate its usability from teachers' perspective. We intend to further investigate what the students' experience will be, and how the interaction methods and metaphors of the games created with the use of the ELG authoring environment can best present content and motivate students to acquire knowledge and skills. We also plan to perform research and development on the interoperability between the ELG and the existing adaptive testing systems (Guzman, Conejo and Perez-de-la-Cruz, 07).

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References

[Bailey, Hsu and DiCarlo, 99] Bailey, C.M., Hsu, C.T., & DiCarlo, S.E. (1999). Educational puzzles for understanding gastrointestinal physiology. Advances in Physiology Education, 21(1), S1-S18.

[Burgos, Nimwegen, Oostendorp and Koper, 07] Burgos, D., Nimwegen, C. v., Oostendorp, H.v., & Koper, R. (2007) Game-based learning and the role of feedback. A case study. Advanced Technology for Learning, 4, 2007.

[Carro et al., 02] Carro, R. M., Breda, A. M., Castillo, G., and Bajuelos, A. L. 2002. A Methodology for Developing Adaptive Educational-Game Environments. In Proceedings of the Second international Conference on Adaptive Hypermedia and Adaptive Web-Based Systems (May 29 - 31, 2002). P. D. Bra, P. Brusilovsky, and R. Conejo, Eds. Lecture Notes In Computer Science, vol. 2347. Springer-Verlag, London, 90-99

[Carro et al., 04] Carro, R.M., Freire, M., Martín, E., Ortigosa, A., Paredes, P., Rodríguez, P., Schlichter, J. (2004). Authoring and Dynamic Generation of Adaptive E-Courses. In: Web Engineering. Lecture Notes in Computer Science 3140. Eds: Koch, N., Fraternali, P. andWirsing, M. (Springer-Verlag), 619-620

[Cristea, 07] Cristea, A. I. (2007). Authoring of Adaptive Educational Hypermedia. ICALT 2007: 943-944

[Diller-Hass, 04] Diller-Hass, A. (2004). Time to change introductory accounting. The CPA Journal, 74(4), 60-62.

[Games-to-Teach Team, 03] Games-to-Teach Team. (2003). Design principles of next-generation digital gaming for education. Educational Technology, 43(5), 17-33.

[Gee, 05] Gee, J.P. (2005). Game-like learning: An Example of situated learning and implications for opportunity to learn. Available at (accessed on June 2008): http://www.academiccolab.org/resources/documents/Game-Like Learning.rev.pdf

[Guzman, Conejo, Perez-de-la-Cruz, 07] Guzman, E., Conejo, R., and Perez-de-la-Cruz, J. (2007). Improving Student Performance Using Self-Assessment Tests. IEEE Intelligent Systems 22, 4 (Jul. 2007), 46-52

[Helliar, Michaelson, Power and Sinclair, 00] Helliar, C.V., Michaelson, R., Power, D.M., & Sinclair, C.D. (2000). Using a portfolio management game (Finesse) to teach finance. Accounting Education, 9(1), 37-51.

[Hoffjan, 05] Hoffjan, A. (2005). Calvados—A business game for your cost accounting course. Issues in Accounting Education, 20(1), 63-80.

[IMS] IMS Question and Test Interoperability Specification, Available at (accessed on June 2008): http://www.imsglobal.org/question/

[Kiili, 04] Kiili, K. (2004). Digital game-based learning: Towards an experiential gaming model. Internet and Higher Education, 8, 13-24.

[Leong, 05] Leong, L. (2005). Improving students' interest in learning: some positive techniques. Journal of Information Systems Education, 16(2), 129-132.

[Malone, 82] Malone, T. W. (1982). Heuristics for designing enjoyable user interfaces: Lessons from computer games. In Proceedings of Human Factors in Computer Systems. Gaithersburg, Maryland, USA.

[Massey, Brown and Johnston, 05] Massey, A.P., Brown, S.A., & Johnston, J.D. (2005). It's all fun and games…until students learn. Journal of information Systems Education, 16(1), 9-14.

[Prensky, 01] Prensky, M. (2001). Digital game based learning. New York, NY: McGraw Hill.

[Prensky, 06] Prensky, M. (2006). Don't bother me, mom, I'm learning! St. Paul, MN: Paragon House.

[Reigeluth, 99] Reigeluth, C.M. (1999). Instructional-design theories and models: A new paradigm of instructional theory. Volume II, Mahwah, NJ: Erlbaum.

[Reigeluth and Squire, 98] Reigeluth, C.M., & Squire, K.D. (1998). Emerging work on the new paradigm of instructional theories. Educational Technology, 38(4), 41-47.

[Rotter, 04] Rotter, K. (2004). Modifying "Jeopardy!" games to benefit all students. Council of Exceptional Students, 58-62.

[Salen and Zimmerman, 03] Salen, K., & Zimmerman, E. (2003). Rules of play: Game design fundamentals. MIT Press, Cambridge, MA, USA, October 2003.

[Tanner and Lindquist, 98] Tanner, M.M., & Lindquist, T.M. (1998). Using Monopoly and teams-games-tournaments in accounting education: A cooperative learning teaching resource. Accounting Education, 7(2), 139-162.

[Van Eck, 06] Van Eck, R. (2006). Digital game based learning: It's not just the digital natives who are restless. EDUCAUSE Review, 41(2), 16-30.