A Delphi Study on the Design of Digital Educational Games

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Abstract. The biggest challenge for the Digital Educational Games Design refers to how to integrate game mechanics and learning mechanics into the gameplay in order to enhance motivation and engagement and improve learning outcomes. This study is the pilot phase of a Delphi method that proposes guidelines for the design of Digital Educational Games. The participants of the Delphi study were academic experts from the scientific field of Digital Educational Game Design. In the first round of the study, a questionnaire of six open-ended questions was sent. The second round questionnaire consisted of 46 closed-ended questions in order to estimate agreement between the participants. The third round questionnaire consisted of one open-ended question. According to the results of the study, the learning and game mechanics elements that have been suggested by the participants as the most important elements are those that promote constructivism, authentic learning environments, personalized learning, and fun. The experts mentioned as very important and challenging element, the way learning mechanics should be integrated into the context of the gameplay. What is proposed to achieve the learning objectives and bring the maximum extent of engagement into the game, is that the learning objectives should be included in activities that do not clearly reveal the learning objectives themselves but incorporate them into symbolic representations of everyday life experiences and examples, that are fun for the users and motivate them for high interaction during the gameplay.

Keywords: Digital educational games · Design guidelines · Delphi method

1 Introduction

In recent years, research in the field of Digital Educational Games has shown positive contributions to learning as far as K12 education, higher education, elderly people, and training are concerned [1]. The positive contribution mainly refers to motivation, engagement and learning outcomes in terms of skills of the 21st century [2]. However, much work has still to be done in order to learn how to better design, and evaluate digital games across different learning contexts and target audiences [3].

The basic features of a digital game can firstly be divided into two main categories, the Learning Mechanics (LM) and the Game Mechanics (GM). LM includes all the concepts related to learning principles, instructional models and teaching techniques,

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learning objectives, skills development, etc. [4]. GM includes all the elements that structure a game and describe the gameplay such as avatars, 2D/3D environments, virtual money, points, timers, feedback (reward, penalty, etc.), narrative (story), rules, goals, competition, levels, cut scenes etc. [5].

Most of the educational games that have been designed are based on the considerations relevant to the traditional learning context. There is a lack of the use of modern learning theories and models such as exploratory learning, problem-based learning and active learning [4]. However, digital educational games support features such as high user interaction, feedback, personalized teaching, teamwork, authentic learning frameworks that do not match with traditional learning [1].

What is more, educational games do not document the design they follow (learning theories, learning objectives, learning techniques etc.) [5].

This suggests that appropriate design models are needed in order to facilitate and guide educational game designers to work more efficient.

2 Related Work

Several studies have been conducted in the context of creating models, methodologies and conceptual frameworks for the design of digital educational games [1, 4–34]. The biggest challenge for the design of the games refers on how well the models can describe the relationships between the different components that consist the digital educational games. This challenge actually includes the ways LM and GM integrate into learning activities through gameplay in order to create learning environments to enhance motivation and engagement and improve learning outcomes.

A review of the literature concerning the models, methodologies and conceptual frameworks for the design of digital educational games shows that the researchers [1, 4–34]:

- Propose general guidelines based on pedagogical approaches without using their corresponding instructional strategies in the gameplay.
- Do not describe the connection between the game elements and the learning objectives of the game.
- Do not describe how to integrate the LM elements into the gameplay.
- Describe the learning and game elements per se, but not the relation between them.
- Do not classify the individual components of a game.
- Do not incorporate an explicit guide for the game design.
- Approach the game design only from a game developer perspective.

Moreover, in most of these studies the methodology is based on empirical data where users are the participants who they are called to design or/and evaluate a given model or methodology or conceptual framework. The users do not have the scientific background to support the design evaluation as they come from different scientific fields. In few cases, game designers are also used as participants. Similar issues apply in this situation, too. Game designers seem that do not transfer the scientific expertise of the necessary instructional design for an educational game to evaluate the game design.

This study proposes guidelines for the design of digital educational games by using the Delphi method, where academic experts of the specific scientific field participate. The guidelines proposed by this pilot Delphi study refer to the LM and GM that educational games should include as well as the ways that learning activities should be integrated into the gameplay.

3 Methodology

The Delphi study was conducted online via questionnaires in Google forms and included three rounds. Five academic experts in the field of Digital Educational Game Design participated. The participants had a period of two weeks to fill in their responses to the questionnaires. Consensus was equaled with 70% agreement among the respondents.

In the first round, a questionnaire of six open-ended questions was sent. The questions were related with the LM and GM that should be incorporated in the games, suggestions about the way that learning activities should be integrated into the gameplay and about the procedure and the challenges of the game design. The participants were asked for at least six opinions per question. The data collected from this initial round followed the content analysis technique. The data were analyzed by grouping similar opinions/items together after the process of determining the most important issues between them.

Subsequently and based on the analysis of the first round answers, a second round questionnaire consisting of 46 closed-ended questions, was configured. The questionnaire included the participants' answers from the first round in order to be rated about their importance through a 9 point Likert scale (1 = no importance, 2 = very low importance, 3 = low importance, 4 = slightly important, 5 = neutral, 6 = moderately important, 7 = high importance, 8 = very high importance, 9 = extremely important). This was followed by the collection and analysis of the second round questionnaire's answers, according to quantitative techniques in order to estimate the agreement between the participants' responses.

According to those results, the questionnaire of the third round was prepared. The third round questionnaire consisted of one open-ended question were participants were asked to describe an exemplary snapshot of an educational digital game for any age or subject of their preference, which combines learning and game mechanics. Data collected from the third round followed the content analysis technique as in the initial round.

4 Results

4.1 First Round

Concerning the LM elements that participants considered that should be included in digital educational games, their answers are summarized below:

- Actions/tasks, challenging activities, competition, problem solving, because the student gets more motivated and engaged.
- Appropriate, constructive feedback, because the student needs it in order to learn from his/her actions.
- Experimentations, because the student should have opportunities to form hypotheses and test them through experimentation, being an active way of learning.
- Exploration, Discovery, because the student gets more engaged and motivated when he/she takes part in active learning.
- Role-playing, because the student gets more empathy, critical and social skills.
- Simulations, because they transfer real-life phenomena that are difficult to otherwise explore, but crucial in constructing meaning and understanding.
- Discussions, social interactions, collaboration activities, because the student can learn interacting with others.
- Assessment, because the student needs to self-monitor his/her performance and gets motivated when he/she progresses.

Moreover, investigation of learners' previous knowledge test and scaffolding activities were also mentioned. Overall, the participants mentioned that LM must be always selected according to the learning objectives of the game.

Referring to the GM elements that participants considered they should be included in games, the answers are summarized below:

- Rules of the gameplay: rules provide a constraining and support strategy necessary for learning and playing.
- Cut scenes: they can easily situate the student within the game narrative and the tasks that he/she is called to undertake, and they can offer information that are relevant to the game's learning objectives.
- Scoring mechanism (e.g. action points), visible progress and levels: gathering action points or unlocking a new level can be very motivational for the student. Furthermore, designing various levels offers the student variety and enables a better organization of the game's learning activities.
- Collecting and interacting with objects: exploring a digital environment in order to discover interactive objects that offer opportunities for experimentation can support active learning. Collecting objects can also be motivational.
- Challenges: motivational well-designed challenges that are in accordance with the game's learning objectives are at the core of an educational game.
- Appropriate, constructive feedback: the student needs it in order to learn from his/her actions.
- Multiplayer capabilities: social interactions may foster learning.
- Simulations: they can bridge the gap between the real world and the game's world.
- Movement in the digital environment, sensation of exploration, realism: students usually like to be situated within a digital environment that consists of various spaces, which they can explore. In addition, this 'spatial metaphor' can help the game designer to better organize the challenges that he/she will embed in the game.

In addition, the adaptation to the learner's needs (learning style, misconceptions) was mentioned. The participants mentioned that the appropriate GM would depend on the entertainment and fun goals of the game.

As far as the ways that learning activities should be integrated into the gameplay, this could be managed by converting learning activities into challenges that the student has to resolve and by meaningfully integrating those challenges in the context of the game with relevant GM into an engaging and fun narrative. In addition, the results show that the learning activities should be integrated in the context of the game by authentic learning approach, by incorporating real world problem-solving activities. That means that the connection between learning and GM should be so well made that the learner typically will not be consciously aware of the learning objectives of the game until he or she is already highly engaged. The participants also mentioned that the integration of learning activities into the gameplay depends on the specific game by considering the specific high level educational and entertainment requirements.

Regarding the procedure (stages/steps) for the design of digital educational games, the answers are summarized below:

- Take into account modern pedagogical approaches, e.g. constructivism, multiple intelligence theory, social theories of learning.
- Take into account basic game-based learning principles.
- Define the learning objectives and sub-objectives.
- Connect the learning objectives and sub-objectives with the acts of the game.
- Define the scoring mechanism as well as the game's levels.
- Define the possible actions that the player can take within the digital environment and the corresponding feedback that he/she can get.
- Design the scaffolds that the player will be offered.
- Evaluate the game with experts (teachers and usability experts).
- Evaluate the game by using real students.
- Redesign the game after evaluation.

As far as it regards the challenges during the game design, the main challenges according to the participants' answers were as follow:

- To transfer the basic aspects of modern pedagogical approaches into educational game-design principles.
- To create appropriate challenges in accordance with the specific learning objectives.
- To create an interesting, persuasive narrative.
- To create appropriate challenges that are motivational and not explicitly didactic.
- To incorporate feedback by using the appropriate GM.
- To have different professionals (e.g., graphic designers, game designers, programmers, educators) cooperating in order to design and develop the game.

4.2 Second Round

Figure 1 shows the results of the second round. The results concern the importance of the LM that should be included in digital educational games.

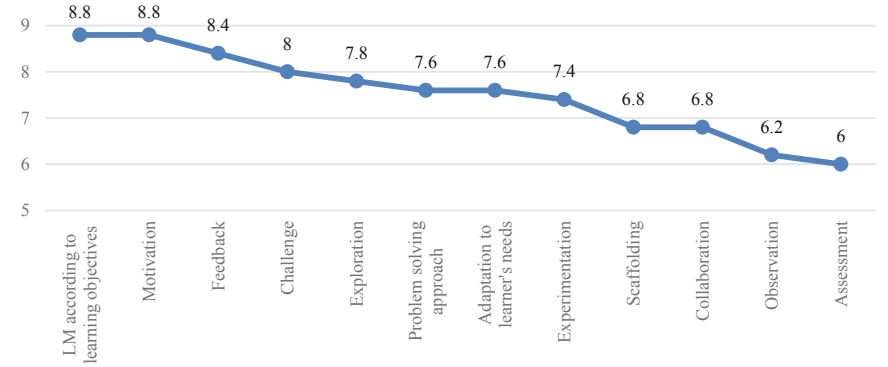

Fig. 1. Average of importance rate about which Learning Mechanics elements should be incorporated into a digital educational game (1 = not at all important, 9 = extremely important)

The participants mentioned assessment, observation, collaboration and scaffolding as least important LM elements. They commented that these four elements depend only on the learning objectives, and not on the game design.

Figure 2 shows regarding the results concerning the importance of the GM elements that should be included in the games.

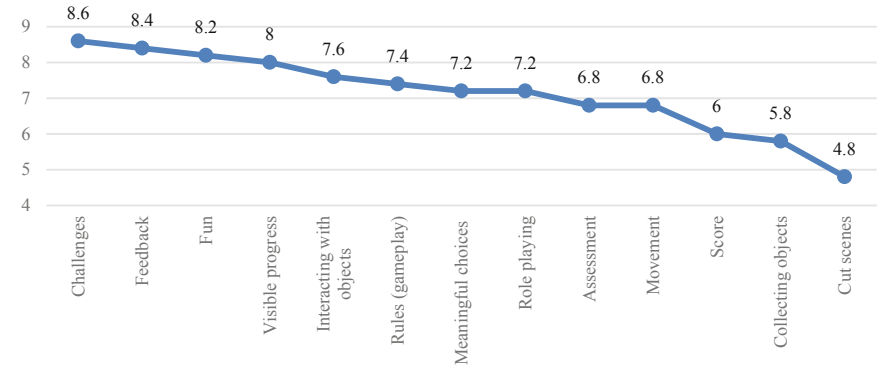

Fig. 2. Average of importance rate about which Game Mechanics elements should be included in a digital educational game (1 = not at all important, 9 = extremely important)

Movement is the least important element, as participants said that it depends on the game and should only be used only if required by the learning and game objectives. Score mentioned to be not so important because the progress could be indicated in other more meaningful ways. Collecting objects is also not important because it depends on the game's learning objectives and should be used if it is required for experimentation, problem solving, or rewards. Finally, cut scenes are not so important because their use should depend on the game and it is not necessary for every game.

As far as the importance of the stages/steps that should be parts of the procedure for the design of digital educational games, the results are follow in Fig. 3.

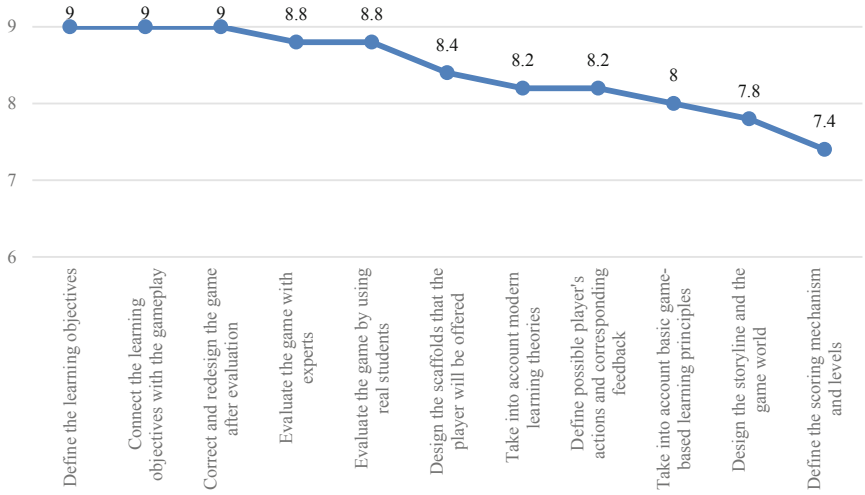

Fig. 3. Average of importance rate about the stages/steps that should be parts of digital educational game design (1 = not at all important, 9 = extremely important)

The results show that the highest and maximum rate is related to the learning objectives themselves, that is the connection of the learning objectives with gameplay, and the evaluation of the game. The lowest rate concerns the design of the storyline and the game environment and defining the scoring mechanism as well as the game's levels.

Figure 4 shows the importance of the challenges that designers face during the game design.

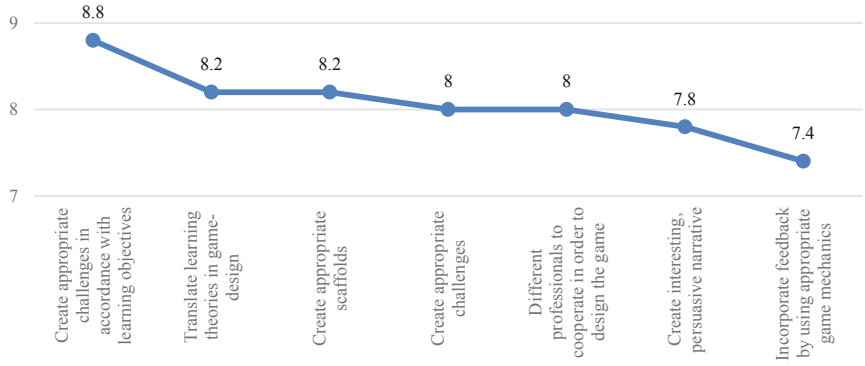

Fig. 4. Average of importance rate concerning the main challenges during the digital educational game design (1 = not at all important, 9 = extremely important)

In the highest rate of all challenges is the design of the appropriate challenges according to the learning objectives

Tables 1 and 2 show the percentages of agreement between the participants of the study. More specifically, Table 1 shows the importance of LM and GM elements for digital educational games design, while Table 2 shows the importance of the stages/steps of the procedure for the design of digital educational games and challenges during the game design.

Table 1. Percentage of agreement among the experts concerning the importance of LM and GM elements in digital educational games

Importance of LM	Rate of agreement (%)	Importance of GM	Rate of agreement (%)
LM selected according to the learning objectives of the game	95	Feedback	93
Motivation	95	Challenges	93
Observation	93	Meaningful choices	90
Feedback	93	Visible progress	90
Challenge	85	Fun	88
Exploration	85	Assessment	88
Assessment	83	Collecting objects	83
Experimentation	78	Interacting with objects	75
Adaptation to the learner's needs	78	Rules (game play)	73
Scaffolding	75	Movement in the virtual environment	73
Problem solving approach	75	Role playing	73
Collaboration	73	Score	63
		Cut scenes	63

The percentage of agreement among the experts of the field is extremely high for the majority of the elements proposed.

4.3 Third Round

In the third round, the participants were asked to describe an exemplary snapshot of an educational digital game for any age or subject of their preference, which combines effectively LM and GM.

The examples that the experts gave describe the connection between LM and GM by following an authentic learning approach, by incorporating real world problem-solving activities in a way that the learner typically would not be consciously aware of the learning objectives of the game until he or she is already highly engaged.

Table 2. Percentage of agreement among the experts concerning the importance of the stages/steps of the procedure for the design of digital educational games and challenges during the game design

Importance of stages/steps of the procedure for the design of educational digital games	Rate of agreement (%)	Important challenges during the game design	Rate of agreement (%)
Define the learning objectives	100	Create appropriate challenges in accordance with learning objectives	95
Connect the learning objectives with the gameplay	100	Create appropriate scaffolds	95
Correct and redesign the game after evaluation	100	Incorporate feedback by using the appropriate GM	93
Evaluate the game with experts	95	Different professionals to cooperate for the design of the game	85
Evaluate the game with students	95	Transfer pedagogical approaches in game-design	83
Design the scaffolds	88	Create appropriate challenges	83
Take into account modern pedagogical approaches	83	Create an interesting, persuasive narrative	80
Define possible player's actions and corresponding feedback	83		
Take into account basic game-based learning principles	78		
Design the storyline and the game world	75		
Define the scoring mechanism as well as the game's levels	70		

5 Discussion

This Delphi study proposes the pilot phase of a study that proposes guidelines for the design of digital educational games.

Our results show that the most important elements for the design of digital educational games is the clear description of the learning objectives and their integration into the context of the game by selecting the appropriate constructive LM elements and approaches as well as the GM elements that promote active learning. The LM and GM elements that have been suggested by the experts as the most important elements are those that promote constructivism, authentic learning environments, personalized learning and fun.

The experts mentioned the way the LM elements should be integrated into the context of the gameplay as the most important and challenging point for the design of

the digital educational games. The learning objectives should be included in activities that do not clearly reveal, but incorporate them into symbolic representations of everyday life experiences and examples that are fun for the users and motivate them for high interaction into the gameplay.

This study is the first attempt to approach the field of digital educational games design by using the Delphi method. Our immediate future plan is the redesign of the Delphi study based on the outcomes of this pilot phase in order to get the more specific guidelines possible for the design of digital educational games for all ages.

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References

1. Annetta, L.A.: The "I's" have it: a framework for serious educational game design. Rev. Gen. Psychol. **14**(2), 105 (2010)
2. Bellotti, F., Berta, R., De Gloria, A.: Designing effective serious games: opportunities and challenges for research. Int. J. Emerg. Technol. Learn. (iJET) **5**(2010), 22–35 (2010)
3. Shaffer, D.W., Squire, K.D., Halverson, R., Gee, J.P.: Video games and the future of learning. Phi Delta Kappan **87**(2), 104–111 (2005)
4. Arnab, S., et al.: A serious game model for cultural heritage. ACM J. Comput. Cult. Herit. **5** (4), 1–27 (2012)
5. Carvalho, B., et al.: An activity theory-based model for serious games analysis and conceptual design. Comput. Educ. **87**, 166–181 (2015)
6. Akilli, G.K., Cagiltay, K.: An instructional design/development model for the creation of game-like learning environments: the FIDGE model. In: Pivec, M. (ed.) Affective and emotional aspects of human–computer interaction – game-based and innovative learning approaches, pp. 93–112. IOS Press, Amsterdam (2006)
7. Amory, A.: Game object model version II: a theoretical framework for educational game development. Educ. Technol. Res. Dev. **55**(1), 51–77 (2007)
8. Björk, S., Holopainen, J.: Patterns in Game Design. Charles River Media, Boston (2004)
9. Buchinger, D., da Silva Hounsell, M.: Guidelines for designing and using collaborative-competitive serious games. Comput. Educ. **118**, 133–149 (2018)
10. Capdevila Ibáñez, B., Marne, B., Labat, J.M.: Conceptual and technical frameworks for serious games. In: Proceedings of the 5th European Conference on Games Based Learning, pp. 81–87. Academic Publishing Limited, Reading (2011)
11. de Freitas, S., Oliver, M.: A four dimensional framework for the evaluation and assessment of educational games. Paper accepted for Computer Assisted Learning Conference 2005 (2005)
12. de Lope, R., López Arcos, J.R., Medina-Medina, N., Paderewski, P., Gutiérrez-Vela, F.L.: Design methodology for educational games based on graphical notations: designing Urano. Entertain. Comput. **18**, 1–14 (2017)
13. Echeverría, A., et al.: A framework for the design and integration of collaborative classroom games. Comput. Educ. **57**, 1127–1136 (2011)

14. El Mawas, N.: An architecture for co-designing participatory and knowledge-intensive serious games: ARGILE. In: Proceedings of the International Conference on Collaboration Technologies and Systems (CTS 2014). Minneapolis, USA (2014)
15. Gunter, G.A., Kenny, R.F., Vick, E.H.: Taking educational games seriously: using the RETAIN model to design endogenous fantasy into standalone educational games. Educ. Technol. Res. Dev. **56**(5–6), 511–537 (2007)
16. Huynh-Kim-Bang, B., Labat, L.-M., Wisdom, J.: Design patterns in serious games: a blue print for combining fun and learning (2011). http://seriousgames.lip6.fr/DesignPatterns/designPatternsForSeriousGames.pdf. Accessed 17 Sep 2018
17. Kelle, S., Klemke, R., Specht, M.: Design patterns for learning games. Int. J. Technol. Enhanced Learn. **3**(6), 555–569 (2011)
18. Kiili, K.: Digital game-based learning: towards an experiential gaming model. Internet Higher Educ. **8**, 13–24 (2005)
19. Kordaki, M.: A 7-step modeling methodology for the design of educational constructivist computer card games: results fron an empirical study. Special Issue of Recent Patents on Computer Science on "Technology-Centered Higher Education: Best Approaches and Practices in Technology Integration" (2015)
20. Lim, T., Louchart, S., Suttie, N., Ritchie, J.M., Aylett, R.S., Stanescu, I.A., et al.: Strategies for effective digital games development and implementation. In: Baek, Y., Whitton, N. (eds.) Cases on Digital Game-Based Learning: Methods, Models, and Strategies, IGI Global, pp. 168–198. Information Science Reference, Hershey (2013). https://doi.org/10.4018/978-1-4666-2848-9.ch010
21. Lindley, C.A.: Game taxonomies: A high level framework for game analysis and design. Gamasutra **2003**(10), 03 (2003)
22. Marne, B., Wisdom, J., Huynh-Kim-Bang, B., Labat, J.-M.: The six facets of serious game design: a methodology enhanced by our design pattern library. In: Ravenscroft, A., Lindstaedt, S., Kloos, C.D., Hernández-Leo, D. (eds.) EC-TEL 2012. LNCS, vol. 7563, pp. 208–221. Springer, Heidelberg (2012). https://doi.org/10.1007/978-3-642-33263-0_17
23. McMahon, M.T.J.: The DODDEL model: a flexible document-oriented model for the design of serious games. In: Connolly, T., Stansfield, M., Boyle, L. (eds.) Games-Based Learning Advancements for Multi-Sensory Human Computer Interfaces: Techniques and Effective Approaches. Information Science Reference, Hershey (2009)
24. Moreno-Ger, P., Martínez-Ortiz, I., Sierra, J.L., Fernández-Manjón, B.: A content-centric development process model. Computer **41**(3), 24–30 (2008)
25. Moya, S., Tost, D., Grau, S., von Barnekow, A., Felix, E.: SKETCH'NDO: a framework for the creation of task-based serious games. J. Vis. Lang. Comput. **34–35**, 1–10 (2016)
26. Plass, J.L., Homer, B.D.: Educational game design pattern candidates. J. Res. Sci. Teach. **44**, 133–153 (2009)
27. Arnab, S., et al.: Mapping learning and game mechanics for serious games analysis. Br. J. Educ. Technol. **46**(2), 391–411 (2015)
28. Salen, K., Zimmerman, E.: Rules of Play: Game Design Fundamentals. MIT Press, Cambridge (2004)
29. Sanchez, E.: Key Criteria for Game Design. A Framework. MEET Project. European Commission (2011)
30. Sicart, M.: Designing game mechanics. Int. J. Comput. Game Res. **8**(2), 1 (2008)
31. van Staalduinen, J.P., de Freitas, S.: A game-based learning framework: linking game design and learning outcomes. In: Khyne, M.S. (ed.) Learning to Play: Exploring the Future of Education with Video Games, pp. 29–54. Peter Lang, New York (2011)

32. Westera, W., Nadolskl, R.J., Hummel, H.G.K., Woperels, I.G.J.H.: Serious games for higher education: a framework for reducing design complexity. J. Comput. Assist. Learn. **24**, 420–432 (2008)
33. Wouters, P., Oostendorp, H.V., Boonekamp, R., Spek, E.V.D.: The role of Game Discourse Analysis and curiosity in creating engaging and effective serious games by implementing a back story and foreshadowing. Interact. Comput. **23**(4), 329–336 (2011)
34. Yusoff, A., Crowder, R., Gilbert, L., Wills, G.: A conceptual framework for serious games. In: Aedo, I., Chen, N.S., Sampson, K.D., Zaitseva, L. (eds.) Proceedings of ICALT 2009, 9th IEEE International Conference on Advanced Learning Technologies, pp. 21–23. University of Southampton, Southampton (2009)