Serious Game for Teaching Statistics in Higher Education: Storyboard Design

Tiago Barbosa[1(✉)], Sérgio Lopes[1,3], Celina P. Leão[2,3], Filomena Soares[1,3], and Vitor Carvalho[3,4]

[1] Department of Industrial Electronics, School of Engineering, University of Minho, Campus of Azurém, 4800-058 Guimarães, Portugal
tijbarbosa@hotmail.com,
{sergio.lopes, fsoares}@dei.uminho.pt
[2] Department of Production and Systems, School of Engineering, University of Minho, Campus of Azurém, 4800-058 Guimarães, Portugal
cpl@dps.uminho.pt
[3] R&D Algoritmi, Campus of Azurém, 4800-058 Guimarães, Portugal
[4] IPCA-EST-2Ai, Campus of IPCA, 4750-810 Barcelos, Portugal
vcarvalho@ipca.pt

Abstract. Serious games can be used as a way to transmit knowledge to the users/students, playing the role of a pedagogical tool in their learning process. Following this idea, a serious game on Statistics is developed for higher education level, promoting and demonstrating the applicability of statistics concepts in day-to-day life and in the decision-making process. The proposed idea is to create a challenging environment (mystery that needs to be solved), where the clues are contextualized in the statistics area through the practice of probability knowledge, confidence intervals and hypotheses tests. According to the student's answers and choices, the game branches out leading the player to different activities/challenges, guaranteeing that, by the end of the game, the student has a better understanding of the subject. In the present paper, the storyboard and the student competencies are presented and discussed, focusing on the project's main objectives.

Keywords: Serious game · Statistics · Storytelling · Adaptive interaction

1 Introduction and Background

Within the scientific and academic communities, there is no doubt that serious games represent an efficient and engaging tool, used for improvements in the learning process [1–5]. Serious Games (SG) are developed to be used as a learning tool in wide areas and different levels of knowledge [3], being STEM field (Science, Technology, Engineering, and Maths) and health the most common. Higher education has also proved to be another area of concern in the development of SG, presenting positive results and contributions [6–8]. Moreover, serious games benefit skill's development, namely communication, creativity and adaptability competences [6]. Despite the positive features mentioned above, researchers recognize that much improvements remain

A. L. Brooks et al. (Eds.): ArtsIT 2018/DLI 2018, LNICST 265, pp. 169–175, 2019.
https://doi.org/10.1007/978-3-030-06134-0_18

to be made, namely in the design phase, in order to not compromise the success of SGs as a learning tool and encouraging the interest of students in specific areas of knowledge [2, 5, 8].

Following these trends and ideas, this work proposes a serious game on Statistics in higher education, an area where engineering students fail and it is still considered by many as not relevant to their courses [9].

Two types of Serious Games that most accurately describe the games related to this paper are Adaptive Serious Games (ASGs) and Sand Box Serious Games (SBSGs).

Motivation is a key element of learning, as it improves student's knowledge retention. Tutors/teachers play a crucial role in captivating and grabbing student's attention, having to provide them with an adaptive and scalable level of challenge, that matches each student's unique profile, competences and progress [10–13]. Serious games growth in popularity led to research on how to include these requirements in a virtual environment, allowing the implementation of personalized learning experience algorithms, where technology takes the role of a "virtual private tutor" [12]. These types of SGs are also known as Adaptive Serious Games. These games provide players with a personalized experience, balancing challenges according to players' needs and difficulties, trying to fill the gaps in their knowledge, motivating them to continue playing. Further research on ASGs led to the formalization of the Competence-based Knowledge Space Theory (CbKST) framework, which tries to provide the basic concepts and strategies to structure and relate a finite set of competences to their respective prerequisites. Following, two SGs that use an adaptive strategy, ELEKTRA [11] and The Journey [12], where the later uses the CdKST framework.

Sandbox, also known as open-world or free-roaming, is a style of video games, characterized by the freedom that players have to explore the virtual world, as well as freely select the various tasks and challenges spread across it. This style inherent freedom and ability for players to choose their own path in the game, presented itself as a perfect scenario to build SGs and explore specific educational domains [10, 13], creating the Sand Box Serious Games. By encouraging players to explore and interact with the environment, by solving different problems or puzzles in the form of quizzes, mini-games or conversations, this type of SG provides a strong basis for configurable software templates that can be easily shaped for various pedagogical intents.

From the conducted literature review, it is possible to conclude that most concepts of Statistics in higher education are not tackled by the serious games found and researchers recognize that much improvements remain to be made, namely in the design phase of serious games.

2 Storyboard

Although some games rely heavily on their mechanics (e.g. Simulations) and their focus solely on the story (e.g. Visual Noves), most try to balance both. The proposed Serious Game tries to achieve just that, providing players with an engaging and personalized storytelling as well as interesting mechanics.

Figure 1 depicts an overview of the structure and flow of the game, which is divided into four main stages: exposition, rising action, climax and falling action. It is

usually possible to discern each of these stages in any structured story, either being a novel or a video game storytelling, which makes them guidelines for the writing of a new one. All the examples provided in this topic are sample case scenarios of the proposed Statistics SG.

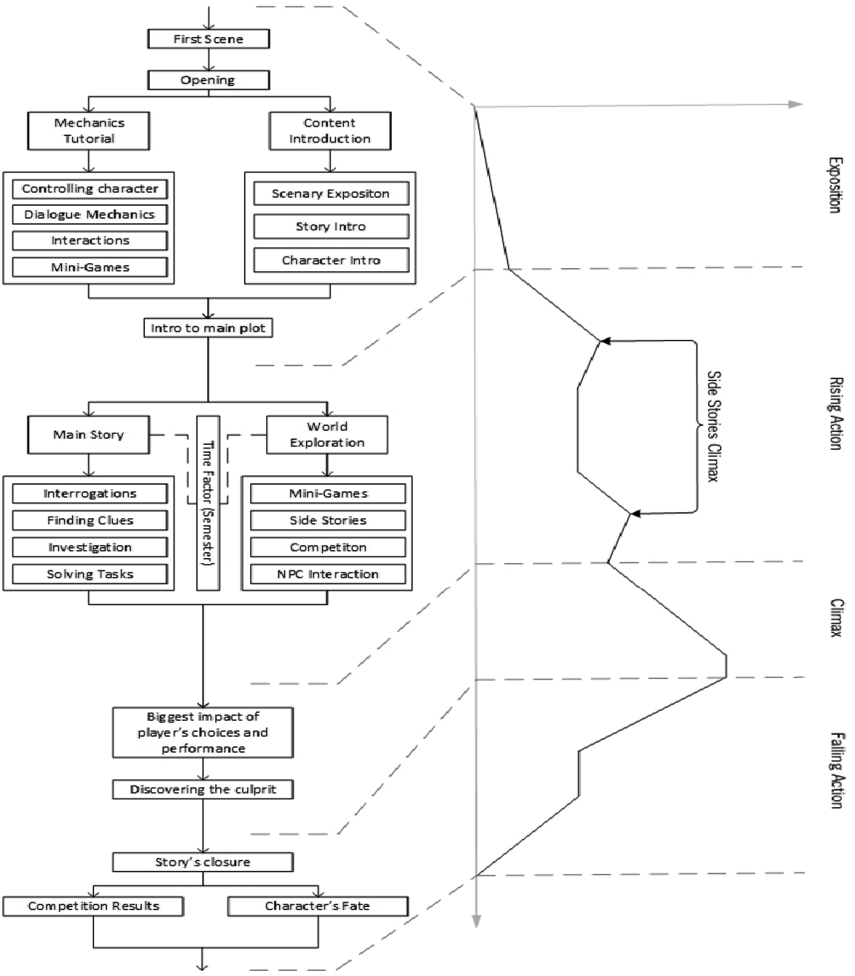

Fig. 1. Serious game structure

2.1 Exposition Phase

Most video games start with an Exposition phase, wherein the player is introduced to the game's story, world and mechanics. It is important, that by the end of this phase, players understand the nature and main scenario of the game, as well as acquired a basic understanding of the game's style and mechanics, like movement, interactions, dialogue and task system. The first scene of the Exposition phase is usually an

introductory one that poses questions to catch players' attention and motivates them to keep playing by answering the questions. As an example, the first scene could be a cutscene that starts by showing the context of a university (e.g., a known building facade) and a Mechanics' laboratory, during the night, proceeding to focus on a single room in that building and assuming the point of view (POV) of a hard-working student finishing some project's work. Satisfied with his/her progress, and eager to check, the results of the tests running on the computer on the next day, the character leaves the room, stepping into an ampler space (the Mechanics' lab), filled with machinery of all kinds, where, unexpectedly, he/she meets a professor. Seemingly distraught for being caught off guard in the lab that late at night, the professor immediately rebukes the student for wandering around and demands an explanation for his/her presence, coming as being a sullen and strict person. The student, shaken by the professor's reaction, explains his/her motives to be there and presents the proper authorization to use the lab. After this small exchange of words, the scene changes from the student's POV to the player's, showing a character, in such a way that he/she is not recognizable, entering the previous room and walking towards the computer. Being the first scene in a mystery video game, its purpose is to spark players' curiosity and interest to what has occurred and prompt them to find the answers: "Who were the characters in the scene? Why were they in the university so late at night? What were they working on? What happened at the end of the scene?".

As the cutscene ends, the game resorts to visual and/or audio UI elements to portray the end of the current day and the start of a new one, shifting the POV over to a third character: the one players are going to control for the majority of the game, i.e., the player's avatar. This time, players find themselves in control of the avatar's dialogue, while he/she casually chats with friends, at a university's bar, about the end of the holiday season and the start of a new academic year. This creates a great opportunity for some story development, mentioning main story crucial events, as well as introducing new characters.

With some time to spare, the characters decide to enroll on a quick card game, changing the POV and UI of the game to a 2D overview of a table with various characters holding cards. This way players face a new challenge (i.e. mini-game) that requires them to learn new mechanics in order to successfully complete it. In this case, that means learning the card game's rules and how to interact with the different elements on the screen. Being a SG, it is extremely important to make sure that players understand that all mini-games are based on statistics' concepts, and their performance is being monitored and directly influences their final stats.

After completing the mini-game, the player's performance is evaluated and displayed. Then the game returns to the previous scenario bringing a new character into the scene, the one previously introduced working on the Mechanics lab. This event leads to the discussion about a competition involving some of the present characters, providing some details about it and referencing the influence of the main character on the team's success, even though he/she is not an official member. This transmits the competition's importance, hinting to its big role on the story ahead.

From a technical point of view, the entire scene described above, from the chat in the bar to the characters reaching their classes, is seen as a tutorial to make players comfortable with the game, slowly introducing them to the story and the different

mechanics. Although these basic mechanics will be the same throughout the entire game, like the movement of characters and the means of interaction, it is possible to introduce players to different ones later on, mainly through mini-games, providing them with a sense of progression and avoiding the boredom of repetition.

Depending on the complexity of the game, the length of the Exposition Phase may vary. In the example given, this phase should be short, in order to quickly introduce players to the game and make them comfortable playing it, improving knowledge retention.

2.2 Rising Action

The transition between the Exposition Phase and the Rising Action occurs with the introduction to the story's main event, which, in this case happens with the discovery of deleted and modified important documents related to the competition, when both the main character and team members try to check on the progress of the tests mentioned in the first cutscene. This sets the main character on the path to try to discovery the cause of such event and find if someone is trying to sabotage the project's work.

Being the longest phase of the game, the Rising Action encompasses most of the main and side story's events, introducing players to all the mechanics available and different scenarios. Since the example provided is an adaptive serious game built inside a sandbox environment, this phase gives maximum freedom to player's actions, allowing them to interact with the virtual world at their own pace choosing the course of action they desire. More specifically, players are given total control of their avatar and are able to move around the university, interacting with the NPCs to learn more about the current events, engaging in either side stories or mini-games to improve their statistical knowledge and progress in the main story. At this top level, the player (main character), together with some friends, tries to gather as many clues as possible to find the culprit behind the corrupted data. Players' knowledge is gathered during this phase, where the game uses it to understand players' needs and knowledge gaps, in order to provide the necessary tools and activities and to help overcome their difficulties. In some cases, this means blocking the main story progressing, requiring the players to complete more side stories or mini-games, ensuring their readiness for the challenges ahead.

2.3 Climax and Falling Action

All of this effort and progress eventually lead to the climax of the game, where all questions regarding the main story's events are answered and the final most difficult challenge is presented, requesting players to apply all knowledge and skills gathered throughout the entire playthrough, resulting on the most satisfying scene of the game. It is also during this phase that ASGs should handsomely reward players that made good decisions in the story and managed a good performance, giving them a final feel of accomplishment and involvement in the storytelling process.

Finally, at the falling action, players reach the final act of the game, where the game gives some closure to the story and characters.

3 Competencies

Figure 2 represents the map of the pedagogical competencies expected for the players to acquire. After the first introductory concepts are exposed to the player, Bayes theorem and Probability distribution are taught, followed by the central theorem limit and finally inferential statistics. This final topic englobes both confidence intervals, preceded by not only the central theorem limit but also the introductory sampling concepts and the distinction between errors of type 1 and type 2. Throughout the entire game, descriptive statists are presented in a variety of ways.

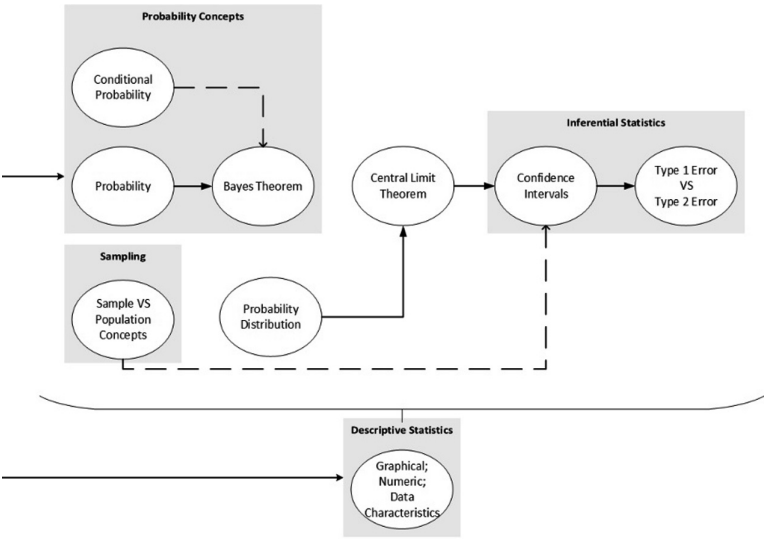

Fig. 2. Learning content structure. Dashed arrows depict dependencies between concepts from different stages of the learning process; straight arrows outline the main learning path. Concepts that can be taught at the same time are represented parallel to each other.

4 Final Remarks

The storyboard of a serious game for statistics learning is given, properly grounded on game theory. The game is designed as a sand box game type with adaptive elements. The player is free to explore a university campus environment in which he/she can carry out multiple activities, and the game reacts to the player achievements on main story's problems. The game reaction consists of additional activities, directly related to the competencies that the player is lacking, which must be completed before progressing in the main story. The next steps are to connect the story with the statists concepts, following both top-down and bottom-up approaches, and develop the game mechanics, always bearing in mind the development of a pedagogical tool that helps students to have a confident attitude towards statistics.

Acknowledgements. The authors would like to express their acknowledgments to COMPETE: POCI-01-0145-FEDER-007043 and FCT – Portuguese Foundation for science and technology within the Project Scope: UID/CEC/00319/2013.

References

1. Popescu, M., et al.: Serious games in formal education: discussing some critical aspects. In: 5th European Conference on Games Based Learning, pp. 486–493 (2011)
2. Girard, C., Ecalle, J., Magnan, A.: Serious games as new educational tools: how effective are they? A meta-analysis of recent studies. J. Comput. Assist. Learn. **29**(3), 207–219 (2013)
3. Boyle, E.A., et al.: An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. Comput. Educ. **94**, 178–192 (2016)
4. Rosyid, H.A., Palmerlee, M., Chen, K.: Deploying learning materials to game content for serious education game development: a case study. Entertain. Comput. **26**, 1–9 (2018)
5. Buchinger, D., Silva Hounsell, M.: Guidelines for designing and using collaborative-competitive serious games. Comput. Educ. **118**, 133–149 (2018)
6. Nadolski, R., et al.: EMERGO: a methodology and toolkit for efficient development of serious games in higher education. Simul. Gaming **39**(3), 338–352 (2017)
7. Barr, M.: Student attitudes to games-based skills development: learning from video games in higher education. Comput. Hum. Behav. **80**, 283–294 (2018)
8. Harackiewicz, J.M., Priniski, S.J.: Improving student outcomes in higher education: the science of targeted intervention. Annu. Rev. Psychol. **69**(1) (2018). https://doi.org/10.1146/annurev-psych-122216-011725
9. Leão, C.P., Soares, F., Carvalho, V., Lopes, S., Gonçalves, I.: A serious game concept to enhance students' learning of statistics. In: Proceedings of the 4th Experiment@ International Conference-Online Experimentation. exp.at 2017, Faro, Portugal. IEEE (2017)
10. Callaghan, M., Savin-Baden, M., McShane, N., Gomez Eguiluz, A.: Mapping learning and game mechanics for serious games analysis in engineering education. IEEE Trans. Emerg. Top. Comput. **5**(1), 77–83 (2017)
11. Kickmeier-Rust, M.D., Albert, D.: Micro-adaptivity: protecting immersion in didactically adaptive digital educational games. J. Comput. Assist. Learn. **26**(2), 95–105 (2010)
12. Dias, J., Santos, P.A., Veltkamp, R.C. (eds.): GALA 2017. LNCS, vol. 10653. Springer, Cham (2017). https://doi.org/10.1007/978-3-319-71940-5
13. Bellotti, F., Berta, R., De Gloria, A., Primavera, L.: A task annotation model for SandBox serious games. In: 2009 IEEE Symposium on Computational Intelligence and Games. CIG 2009, pp. 233–240 (2009)