Digital Game Design as a Complex Learning Activity for Developing the 4Cs Skills: Communication, Collaboration, Creativity and Critical Thinking

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Abstract. In this study, digital game design is analyzed as a team-based knowledge modelling process. In the context of a graduate seminar, the students were organized in teams and were asked to design a serious game. In the early stages of the process, each team had the possibility to engage in a topic suggested by the professor or decide their topic of interest. Half of the teams choose a suggested topic (herd immunity, intergenerational communication, active ageing); the other half proposed a topic of their choice (inuits and micmacs, banker-customer relationship, French as a Foreign Language). In both cases, the students should engage in a participative design process which requires a learner-centered analysis. We analyze both the digital game design process and outcomes of the game design from the perspective of social participation and the 4C competencies deployed in the game design process: communication, collaboration, creativity and critical thinking.

1 Introduction

Digital game design is a knowledge modeling activity for learners of different ages. It engages the learners in a decision-making process of a complex system which includes the narrative, the characters' representation and their behaviors, and the mechanics allowing the user to reach the game objectives. The game creation process engages the learners into a meaningful constructivist activity [1, 2] requiring a high level of creativity and collaboration [3]. Our study aims to analyze a team-based serious game design process from the perspective of knowledge modeling, social participation and the 21st century competencies engaged in the game design process. Those outlined key competencies are communication, collaboration, creativity and critical thinking. In the next section, we introduce game design as a team-based knowledge modeling activity, before exploring the context of the course, the game design process and its outcomes.

2 Game Design as a Team-Based Knowledge Modelling Activity

Games are a structured forms of play [4] which aims at engaging one or more person in an interactive and enjoyable activity. Everyone can create games and define the rules of structured play in analogic contexts. During the 20th century, digital game creation

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required a certain level of computing literacy that prevented non-specialized computer professionals to create games. Nowadays, the evolution of the Internet and game engine platforms makes everyone capable of designing games and even creating playable indie-style games [5–7]. Our interest in the game design activity is not focused in the professional process of creating marketable games, but in the game design activity itself as a sociocultural and knowledge modeling activity [8]. Game creation is an activity that engages the user in the definition of a game universe and scenario based on a real or imaginary socio-historical context, where characters can introduce life narratives and interaction that display either known social realities or entirely new ones. Game creation is a knowledge modeling expression that allows the creation of different game universe and characters. As for knowledge modeling, it is a "cross-disciplinary area that deals with approaches to acquire, refine, analyse, capture, model and describe knowledge in a way so as to facilitate its preservation and to ensure that it can be aggregated, substituted, improved, shared and reapplied" [9, p. 1]. For Jonassen and Land [10], computers could be cognitive tools that support the knowledge modeling process both individually and collaboratively. In the field of computer sciences, knowledge modeling is considered a fundamental activity in the "design of computer-based systems for supporting human cognitive tasks in complex socio-technical systems" [11]. In our study, we engage the learners in the design of a serious game based on a topic related to a social challenge of their choice. By designing the game they should inquire, analyze and model the topic of their social challenge. They have to structure it as a game, including game and learning objectives, narrative mechanics [12, 13], game mechanics and learning mechanics [14].

3 Game Design as Social Participation

Based on the critical play, characterized by Flanagan as "a careful examination of social, cultural, political, or even personal themes that function as alternates to popular play spaces" [15, p. 6], participative critical game design aims to develop games which considers social inclusion from the design process and which are designed or developed by the end-users or who invites end-users to the design and development process in collaboration with other end-users or game professionals. Critical game design aims to develop an awareness of games as socio-cultural objects [16]. The critical game design process also values the knowledge experience of the community members interviewed during the game design process. The result of the digital game design is not the goal; instead, we focus on the critical game design process. The critical game design process is a participative learning experience [1, 17, 18] that is able to engage the game designers with society and the participants in a powerful knowledge modeling activity [19].

4 Participative Game Co-creation Process and Outcomes

4.1 Context

Hybrid Course Enrolled by Onsite and Online Students. The course "Game based learning, serious games and gamification of education" is an elective seminar for the postgraduate students of the master and doctorate program in educational technology of Université Laval (Québec, Canada). The course is enrolled by 24 students (12 onsite students and 12 online students). The majority of online students are located in Canada (n = 11; GMT-5 to GMT-8), excluding one student located in Tunisia (GMT+1).

The course accounts for 3 credits, organized as 3 h per week of synchronous class activity available to online students through the videoconference system Adobe Connect, 3 h of team-based autonomous activity and 3 h of individual activities.

Course Structure. The course is structured in two main periods in order to create two prototypes (Fig. 1).

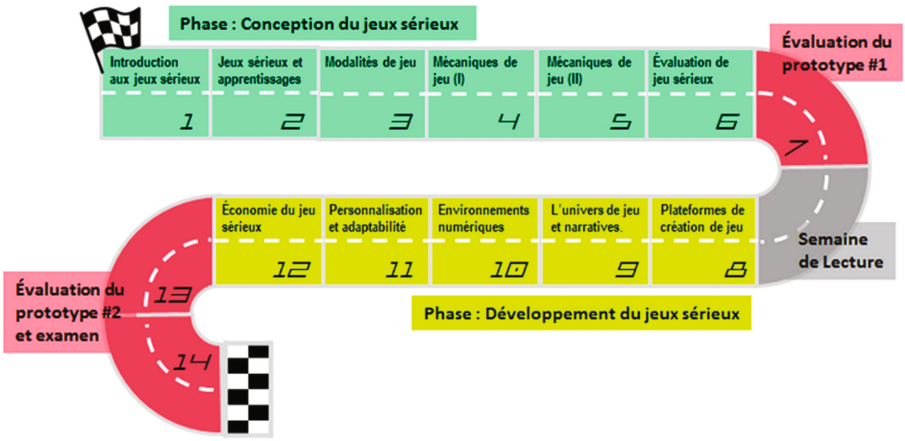

Fig. 1. Course structure and the two main periods and prototypes.

The first prototype should include the learning objectives, the game modalities, the game and learning mechanics, the evaluation strategy of the learning objectives and the evaluation of the gameplay. Based on the feedback received by the panel of experts composed by game development professionals, researchers, the course professor and other students not enrolled in the course, the team should improve the prototype and develop a second release defining the type of technologies they consider the best for their game design. The students are not required to engage in the development of the game. They are only required to produce a mock-up or a sketch of the look and feel and interface of their prototype that could help a third person to understand the game interface and interactivities.

Team Constitution Process. Teams were constituted the first day of the course after an introduction of each of the participants. They had to focus on their main competences in relation to game design. Teams were composed by two onsite students and two online students. A total of 6 teams were constituted during the first session of the course. Each team had the possibility to engage in a topic suggested by the professor or decide their topic of interest. Half of the teams decided to engage on the suggested topics (herd immunity, intergenerational communication, active ageing); the other half engaged in a topic of their choice (aboriginal inuits and micmacs, banker-customer relationship, and French as a Foreign Language). In both cases, the students had to identify the social challenges related to their topic and engage with the community during the serious game design process. The teams having decided to engage on topic suggested by the professor had the 'advantage' of having to their disposition a list of resources that were already selected to facilitate their analysis of their topic. They were also offered to contact specialist in their topic.

Participative Game Design Methodology. The students are introduced to digital game design through a 6 steps methodology aiming to facilitate the decision-making concerning the game modalities, game and learning mechanics and evaluation. The table below introduces the methodological procedure and reflective questions in each of the six steps of the proposed methodology (Table 1).

Table 1. Game design methodology.

Heading level	Font size and style
Learning objectives	Learning objectives are the key point in starting to design the digital game based learning (DGBL) activity. In this step, the students are invited to identify the formal or informal learning context, define which of the learning objectives will be part of the learning assessment and which type of feedback (or group awareness) will be offered as a display of progression to the learners during the game or gamification activity
Learner-centered need analysis	The learner-centered need analysis aims to analyze the learners' prior knowledge and competences (PKC) in order to organize the learning objectives in levels considering the Zone of Proximal Development [20] and the optimal difficulty to try to achieve a certain level of flow [21]. Based on the learners' diversity in terms of PKC, the team could decide to organize the learning modalities in order to adapt the game to the diversity or evaluate the cooperative game dynamics that could help overcome the learners' PKC diversity. The learner-centered need analysis should also analyze the learners' language and computer literacy, their preferences, context and technological resources in order to take decisions in the following steps

(*Continued*)

Table 1. (*Continued*)

Heading level	Font size and style
Game modalities	In order to decide the game modalities, the learners are invited to identify the existing serious games that could fit the learning objectives. In case an existing serious game matches the objectives, they should identify the pedagogical integration requirement. In case there is not an existing serious games fitting the requirements, the teams could decide to repurpose an existing game, such as using *Angry Birds* for learning mathematics. A third alternative is to design and create a game. Furthermore, the teams can opt for educational gamification and add the game components (e.g. public scoring and competitive team, reward system…) to an educational situation All the students enrolled in our course the students decided to create their game because no existing serious games fitted the learning objectives
Game rules, learning and game mechanics	The teams should decide the individual or collaborative context of the game and define the game rules. The game rules should be aligned with the learning objectives (first phase) and the learning assessment and feedback (fifth phase) in order to incentivize the learning progression in the game. The game mechanics structures the interaction and control processes allowing the player to advance in the game. The teams are introduced to the existence of primary and secondary game mechanics [22] and are invited to identify the learning mechanics and game mechanics (LM-GM) based on the LM-GM model proposed by Arnab and collaborators [14]
Learning assessment and feedback	In this phase of the game design methodology, the team should analyze the effective impact of the game on the learning objective achievements. The learning assessment and feedback should derivate from the learning objectives (first phase). According to the needs identified in the second phase (learner-centered need analysis), there are three main types of assessment that could be introduced in the game: diagnostic, formative and summative assessment. Individual and collective feedback could be displayed to the players through knowledge group awareness widgets [23, 24] in order to ensure the learner is aware of her/his progression
Gaming and learning experience	This last phase aims to evaluate the player gaming and (positive) learning experience. The teams are introduced to the works of Kiili in relation to the flow experience [25] and the criteria for improving it. Kiili focus on the importance of immediate feedback, clear goals and challenges that are matched with the current learners' knowledge and skills to place them in the flow activity state

5 Game Design Process

Each of the team has completed the game design successfully. The game design process has been evaluated according the six steps methodology and the assessment criteria associated to each step of the methodology. The game design outcomes have been evaluated by a panel of experts composed by professionals, researchers and other students not involved in the course. The learners 4C's "super skills" for the 21st century (communication, collaboration, creativity and critical thinking) [3] have been evaluated by the professor based on the game design process and team-based tutoring activities (Fig. 2).

Fig. 2. Screenshots of one the games designed by the intergenerational communication team [26].

Game Design Process. The figure below introduces the average results of the teams engaged in a suggested topic by the professor (having received more guidance in the initial steps of the process) and the average results of the teams engaged in a self-defined topic (Fig. 3).

We observe the teams designing a game based on a suggested topic have higher performances in the game design process documentation, the definition of the learning objectives of the game and the learning assessment strategy of the learning strategy. Self-defined topic teams outperform in the learner-centered context analysis, the game universe, game modalities, game mechanics and learning mechanics scores.

Evaluation of the 4Cs. The figure below introduces the average level of the 4Cs skills among the students in the suggested topic teams and self-defined teams (Fig. 4).

We observe that the learners composing the teams working on a self-defined topic clearly outperform their counterparts in the suggested topic teams in terms of communication and collaboration. The learners taking part in the suggested topic teams only show a slight advantage in the creativity skills.

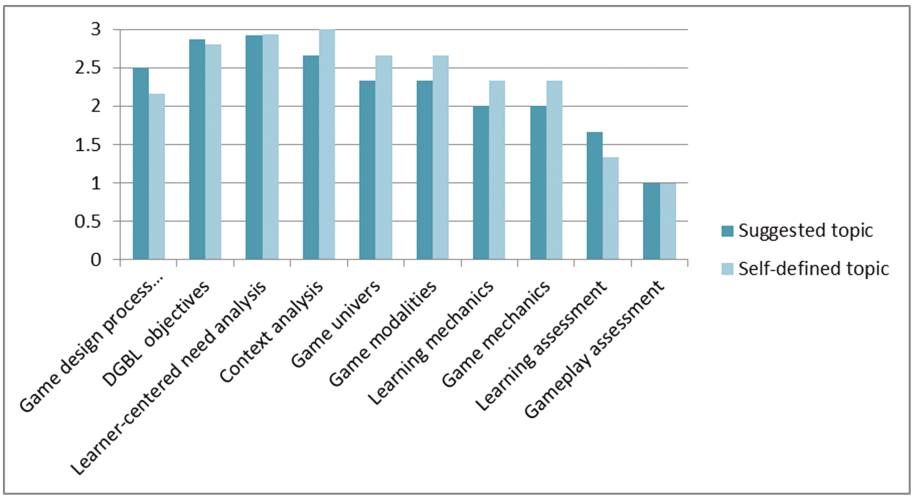

Fig. 3. Average results in the game design process of self-defined and suggested topic teams. (Color figure online)

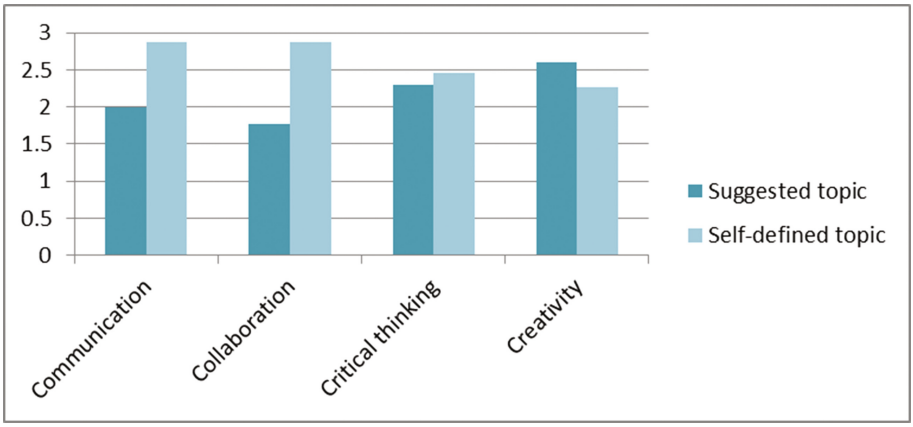

Fig. 4. Average results in 4Cs process of self-defined and suggested topic teams. (Color figure online)

6 Discussion

The graduate students enrolled in the "Game based learning, serious games and gamification of education" course reported a high level of engagement. The students' satisfaction with the course was high: onsite students' showed a 92.4 % of satisfaction in the questionnaire of satisfaction deployed at Université Laval for evaluation the quality of the teaching activities; within the same questionnaire, the online students reported a 88.6 % of satisfaction, which could be due to some of the quality difficulties

in videoconference sessions. The students' reported feeling secure with a step-by-step methodology that allowed them to be creative in their design while having certain guidance in the process.

In terms of the design game process, the evaluation shows differences at the different stages. The 4Cs skills of students having chosen to work on a topic already suggested by the professor and those having preferred to engage in a game design topic of their choice were varying. We can observe that students having preferred a topic already prepared by the professor have better defined the serious games learning objectives and the game design documentation, but their performance is lower in all the other aspects of the game design process than the free-chosen topic teams. We can discuss this result as an initial advantage of having selected an already prepared topic, which helped the teams to focus directly on the learning objectives and documentation in the early stages of the game design process while their free-chosen topic counterparts were still defining what they would work on. However, despite the initial advantage, the teams working on predefined topics were less performant in the subsequent steps of the game design process. We should hypothesize about the possibility that learners having preferred to follow the professor suggestions could have a preference for higher guidance from the professor, which was less available in the subsequent steps of the game design process. We can also discuss this early advantage as a consequence of having more time in the first steps of the game design process than the teams working on defining their own topic.

In terms of the 4Cs skills, we observe that the free-chosen topic teams outperform in communication and collaboration. We can discuss this advantage under the lens of their small group development process [27] which engaged the team members to better know each others' preferences while deciding their serious game topic. At the opposite, the teams working on an already defined topic accelerated their "forming" stage of their group development process which does not developed the same degree of cohesion, communication and collaboration in the subsequent stages.

The differences observed in the teams according their engagement in an already defined topic could be also discussed under the lens of the individual traits of students that prefer to follow the professor suggestions, which shows less autonomy and initiative than their counterparts.

The objective of engaging the graduate students in a knowledge modeling process through a digital game design process has been achieved for all the students and teams. Digital game design is a powerful learning activity that has the capability to engage learners not only in K12 [28] but also in Higher Education [29].

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