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Collaborative game design for learning: the challenges of adaptive game-based learning for the Flipped Classroom

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Abstract. In recent years, game-based learning and gamification have increasingly been used within flipped classroom approaches. Many research showed that both approaches were efficient in conjunction in an active learning perspective. However, we observe that few games have been designed with use in the flipped classroom in mind, and there is therefore potential to improve the flipped classroom experience by approaching the development and integration of games with a more holistic and adaptive experience in mind. For that purpose, a focus group of educators was assembled for a pilot project and their educational practices, objectives and gaming experience analyzed. Following this investigation, co-constructed game design choices were made to try and develop a game that could support a variety of subjects and learning experience in the FC. Although the focus group answers showed that a fully adaptive gaming experience needed, for reasons of flexibility, to lean towards a gamified platform, the final design solution can have the potential to support fully the flipped classroom experience for any subject or class desired.

Keywords: Game design, gamification, learning game applications, flipped classroom

1 Introduction

Interest for learning games has increased since the early 2000s and the discourse regarding the benefits of playful education has become more and more pervasive. While early interest in the educational value of games spawns back decade, in more recent years constructivist approaches and more focus into the articulation between playing, learning and engagement has built learning games as an active research field [1].

In this context, research into game-based learning (GBL) has become a cornerstone of the field of active learning (AL). Active learning, according to Frey [2], "shifts the focus of learning from passively receiving content information to diligently participating in learning activities", and allow students to develop and nurture important skills such as "critical thinking, creativity, communication, and collaboration" and "promotes

social interactions, allowing students to work collaboratively with their peers and teachers". A solid example of active learning approaches is the considerable of the flipped classroom (FC), which is a set of pedagogical approaches that (1) move most information-transmission teaching out of class, (2) use class time for learning activities that are active and social and (3) require students to complete pre- and/or post-class activities to fully benefit from in-class work." [3].

Research into the potential of integrating educational games in the FC is a more recent development that dates back to the past five years. Many studies have shown the potential of using gamification and games in the FC to support students' preparation for class or engage in collaborative in-class activities.

However, although there is a great diversity of approaches in integrating serious games in the FC, few were designed with FC usage in mind. Some common approaches consist in using commercial games for engagement purpose [4], gamifying the pre-class preparation using tools from the virtual learning environment (VLEs) [5], or using serious games as a strictly in-class activity bound by the class temporality and rather detached from the general FC process [6]. A rare outlier could be the example of the game the Protégé [7], designed with the idea of scalable access to learning material in mind, which is a staple of the FC pre-class process.

There is therefore a dearth in FC focused games and our research project, FLIP2G, aims at filling in this gap by developing a gaming system that could be used as a tool for FC implementation. In this research, a focus group of five participants representing both secondary and higher education was gathered, and an open-ended qualitative questionnaire used to determine what were the needs of educators using the FC and wanting to expand the integration of game-based learning in their methodology. From this collaborative design process, the bespoke model for a gaming platform dedicated to the FC and capable of providing an adaptive learning experience was developed and implemented.

2 Related works

2.1 Serious games and gamification

There is extensive research in the potential of games in an educational context. Educational research especially is a domain in which game studies have strayed away from the notion of studying game as an object or system to the study of play as an ensemble of attitudes and activities [10]. The expanding field of playful learning research has covered a wide range of activities introduced as learning tools: digital game-based learning, non-digital games, gamified learning systems, simulation games, and escape rooms to name only a few [11]. For this study, however, we focused on two essential categories: serious games and gamification. A serious game is defined as a game in which education (in its various forms) is the primary goal, rather than entertainment" [12]. While the original definition concerned the field of digital game studies, the term can also apply to non-digital forms of games such as board games and role-playing games. Gamification is an "umbrella term for the use of video game elements to improve user experience and user engagement in non-game services and applications"

[13]. Those two wide definitions allow covering and describing a variety of playful learning experiences.

The game app Kahoot is a solid example of gamification used to great efficiency. Based on a simple quiz system with a timed answer competitive mode, it boasts millions of active users in the world. Several studies have highlighted the game's efficiency in supporting students' engagement in learning. For example, O'Donnell and Gabriel [14] tested the gamified version - through Kahoot - of science course on climate protection for high school students, against a non-gamified version of the same program taught in the control group. Although the gamified version of the curriculum failed to improve the performance of the whole cohort, students in the gamified class presented a more positive feedback on the course and improved knowledge of environmental issues. Similarly, the game platform MaTHiSiS, developed with support from the European Union, provided a mobile platform with several game modules developed to support math education in primary and secondary schools [15].

Research has thus widely underscored the benefits of playful learning and gamification. The meta-study examination carried by Sauve [16] pointed to the effectiveness of games for cognitive, affective and psychomotor learning. Muntean [17] similarly covers how gamification in e-learning can trigger better engagement in participants by involving students in social play and interactions. The efficiency of playful learning has also been connected to improved intrinsic motivation: Bowman [18] through a constructivist approach thus underlines how cognitive, affective and behavioral benefits of educational games trigger better intrinsic motivation and engagement in students. Therefore, the integration of game studies in education has a solid foundation, and this research aims at furthering use of playful learning within the specific context of the FC.

2.2 Serious games in the FC

The FC is a very significant model developed to support active learning and students' autonomy in the past decade. Many reviews of the FC reveal the interest for the method in the scientific and educational discourse. Former reviews make a compelling argument to the efficiency of the FC: student perceptions and engagement toward FC approaches are generally positive, the FC helps to improve students' communication skills and independent learning, and allows teachers to spend more time with students individually (e.g. [19]; [20]; [21]). However, the main limitations of the FC are also well documented, especially the challenge of getting students prepared for class, in a way that supports the learning process in a continuous manner that include personal work and scalable engagement with the learning material [22].

While research into the FC has expanded during the past decade, investigation into the integration of gamification and serious games in the FC is a most recent subject of exploration. Studies of the educational benefits of the FC accelerated in the 2010s fol-

lowing its popularization in the secondary education in the United States [23], and research into the integration of game-based learning in the FC developed in the past five years.

Our own scoping literature review [24] allows us to show an exponential increase of publication on the subject in the years 2017-2019. It also shows that this theme of research has so far being extremely disjointed, covering a wide variety of approaches and initiatives. For example, almost half of the literature was concerned by gamification applied in the FC, a sign of early experimentations mostly relying on VLE traces. Furthermore, we also observe in this study that, in the minority of studies using an actual GBL approach, one out of five studies covered non-digital games, and a similar proportion on the other hand focused on simulation games. Finally, three out of five articles focused on serious games with, again, a huge diversity of approaches ranging from commercial games, curriculum based serious games, coding games, or digital roleplaying games used for contextual practice. We finally observe that different types of games or gamification are used outside of class and in the classroom, showing the versatility of the GBL practice in the FC.

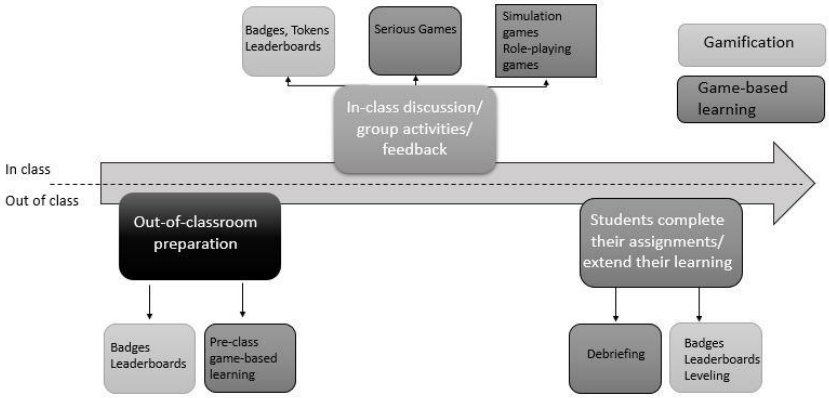

Fig. 1. Synthetic representation of GBL and gamification in the FC (based on Algayres & Triantafyllou [24])

Although games used in the FC cover a large spectrum, they usually focus on specific issues and usually fall in one of the following categories

- Subject-driven curriculum-dependent games that support a very specific curriculum, usually through targeted in-class activities. For example, Lin et al. [25] studied the impact of a game developed on RPG maker targeted towards business university students. The game would pit students against a variety of scenarios meant to reflect real life business challenges and practices.
- Flexible gaming structures or gamification that allow playful learning in a variety of subject, usually used off-class or at the beginning of the class. The purpose of this approach is to support students' preparation for class by scaling the

interaction with the learning material, and engage them in an active manner. The game The Protégé, studied by Ling [7], as mentioned before, offers perhaps one of the most elaborate examples, inviting students to engage with the learning material as they are trying to solve the mystery of a teacher's disappearance. This is an example of meaningful gamification [26], a new approach to the concept of gamification that puts greater focus on user-based experience and engagement beyond simple game mechanics. Similarly, Hung [27] ran a study on the positive impact of a digitally-enhanced board game with QR codes and gamified quizzes to test the preparation of the students at the beginning of each class, and research carried by Estriegana et al. [28] presented the dual integration of gamification for pre-class preparation and in-glass GBL activities.

Studies into the integration of GBL in the FC showed positive learning outcomes for students, who presented better learning performances and less anxiety towards the studied subject [27]. The combination of GBL and the FC also yielded better learning outcomes in terms of performance and engagement than other structures to deliver the curriculum, both against standard non-gamified FC (e.g. [29]; [27]; [30]), and non-flipped game-based learning [25].

Due to our specific constraints, of a European project involving a great number of partners with each their own subjects and challenges, the latter, ore specific approach to integrating GBL in the FC seemed more relevant to our interests.

Our examination of the relevant literature thus led us to believe that there is potential to develop a bespoke gaming experience for the FC that could expand on the best practices already observed, and facilitate the integration of GBL in the FC in a flexible manner that could be used in a variety of subjects and contexts.

2.3 Cognitive benefits and learning objectives

The rationale behind the efficiency of combining GBL and the FC is that, being active learning methodologies, they can complement each other in supporting students' motivation, engagement and self-regulated learning. We define active learning as any method that supports "diligently participating in learning activities" [31] instead of a passive attitude in class. For that purpose, Abeysekera and Dawson [32] used self-determination theory (SDT) to examine the FC in terms of student motivation. They theorized that the FC encourages self-determined forms of intrinsic and integrated extrinsic motivation, by supporting students' sense of competence, autonomy, and relatedness.

Similarly, several studies dealing with the integration of GBL and gamification in the FC quoted self-determination theory as one of the factors that can explain sustained engagement and motivation in students (e.g. [7]; [33]; [34]). In this context, the gaming elements in the program allow for trial and error, thus enabling both a greater sense of autonomy and competence in the students.

Our project therefore aims also at determining the tools and structure through which we can use GBL in the FC in such a way that the motivational and educational benefits of both methodologies could reinforce each other. For that purpose, we aimed at developing a collaborative gaming design that would allow the creation of an adaptive gaming system that could be adapted to any curriculum requirement within the FC.

3 Methodology

3.1 Focus group investigation

The objective of the FLIP2G project is to build a dedicated gaming platform for the FC, that could provide an adaptive experience to a variety of users. The choice of a collaborative co-design made therefore sense in the development stage. Design Participation, or the action of involving end users in the design process, has a long history dating back to the 1970s [35]. According to Lee [35], one benefit of Design Participation is allowing collaboration between scientific design research and creative design research, and bridging the abstract space of design with the concrete space of users.

To that end, our approach to the development of the gaming platform was to work with a specific focus group, comprised of the partners who volunteered to be part of the project and active participants in the pilot tests of the game. The result of the focus group investigation was then the basis for implementation by the game designers. There is a long practice of using focus groups as a tool for educational design research. Focus groups provide a qualitative approach to such purposes as generating ideas among staff for purposes of curriculum development [36], or getting specific understanding of social issues for a certain group [37]. For our purpose, we follow the steps suggested in Morgan et al. [38]: research design, data collection, analysis and reporting of results.

3.2 Research design and data collection

As stated above, the focus group was comprised of the project partners enrolled to be stakeholders in the pilot projects ($n=5$), representing four different nationalities and two types of educational institutions (secondary and higher education). The purpose of the group was to determine the needs for a gaming platform developed to fit a FC model.

Participant code	Country	Institution	Main subjects taught	Student age	Class size
#1	UK	University	Digital business, Mathematics	18-25	10-50
#2	Greece	University	Project management	18-30	20-60
#3	Denmark	University	Programming	18-25	60-70
#4	Norway	Secondary	Social sciences, English	12-16	20-30
#5	Greece	Secondary	Mathematics, History, Geography, Computer	9-15	20-30

Table 1. description of participants

A questionnaire was built which focused on the following themes:

- Subjects and levels that would be taught using the platform
- Conventional learning activities carried out in class
- Objectives pursued in using GBL in the FC

The questionnaire was comprised of six open questions. The participants could write their own detailed answers. Due to the extreme dispersion of participants in the European territory, the questionnaire was conducted online, with a timeframe of two weeks to answer the questions.

Please fill out and return this questionnaire until the 31.10.2019

Which is/are the main subject(s) that you want to teach with Flip2G?

Which is the main age group that you want to teach with Flip2G?

Which traditional learning activities do you like to use in class?

Do you play any "analogue" learning games in class? If so, which?

Which features are missing in traditional learning activities that gaming can help with?

How long are your classes on average and how often do they take place during the week (in one subject)? How much of that time would you use for any gamified content?

Fig. 2. screen capture of questionnaire

The data was synthesized in a thematic table based on the keywords used by each participant.

Partner	Subjects Taught	Age	Class Size	Academical BG	Session Length (h	Sessions	Total hours	Traditional Learning Activities	Games used	Objective of the Game
1	Digital Business	18-25	10 to 50	Business Students	3	6	18	Group Discussions	Online games (cybersecurity simulation game)	More engaging/fun
	Linear Programming							Reading Assignments		Engaging to students who already know the topics
	Mathematics							Exercises (e.g. SWOT)		
								Internet Research (e.g. Analytical)		
2	Project Mgmt	18-30	20-60	Applied Informatics	1 to 2	13	26	Assignments		Integrate assignments & quizzes to the game
	Open Data							Quizzes		Understanding of the learning material
	E-Government							PBL		
3	OOP with Java	18-25	60-70	Undergratudates (CS)	1	10	10	Quizzes		Better understanding
	Android Programming							Programming Exercises		Higher Motivation
								Q&A Rounds		
								Lectures with Slides		
								Demonstrations		
4	Social Sciences	12 to 16	20-30	High Schoolers	1	40	40	Reading Assignments	D&D (tentative)	Audio-visual output
	English							Group Work	OTS digital games (Frostpunk, AC)	tactile input
								Presentations		Easy to engage games that is not as time consuming
								Frontal Teaching		
								Videos		
								Class Discussions		
5	Mathematics	9 to 15	20-30	Middle Schoolers	1 to 2	40	40	Exercises	Riddles	Understanding of material
	Physics							Multiple Choice Quizzes	Kahoot	Adding assignments & quizzes
	History							True / False Quizzes		Increased Motivation
	Geography							Assignments		
	Informatics							Open Quizzes		

Fig. 3. screen capture of response table

4 Results

4.1 Analysis and results: the challenges of collaborative design

The result of the focus group questionnaires showed a few points of convergence, but many points of divergence.

The main similarities resided in the objectives pursued in wanting to introduce a game-based learning approach in the classroom. The main motivation for using the game is to give students better engagement or motivation in their studies and facilitate the understanding of the learning material (three occurrences each). Secondary elements regarding the objectives of the game related to the learning experience of the students: to facilitate the integration and use of assignment and quizzes (two occurrences), and to support the use of game in a way that would feel more organic and less time consuming (one occurrence).

A majority of respondents (three out of five) had previous experience using games in their classroom in different forms: gamification via Kahoot, use of commercial games for educational purpose, and finally use of a cybersecurity simulation game online. While this is cohesive with the fact that partners were volunteers for the project, it also underlined the necessity of developing a game that would be accessible to educators without a prior gaming experience.

All respondents however had various different needs in terms of classes and curriculum. Due to integrating participants of both secondary and higher education, a huge variety of potential subjects was covered, nine in STEM subjects ranging from mathematics to programming, two in economics, and four in Humanities. Similarly, class sizes and session length were of a diverse range, ranging from 20 to 60 students to sessions ranging from one to three hours, with an average length of 1.6 hours.

This diversity of responses showed that a truly adaptive game should be able to adapt to a variety of circumstances, in spite of the fact that participants' objectives were aligned with the objectives of the FC and active learning. In that, the participants in our study reflected the main challenges regarding the implementation of game-based learning, previously identified in other studies such as Meletiou-Mavrotheris and Prodromou [39]: the teacher's gaming literacy and training, the curriculum constraints in space and time, and the resources, both financial and technical.

These challenges and the need to cater to a diverse audience led the design team to choose a gamified structure and develop a platform that would allow scalable access to learning resources and games while allowing for full personalization from the teachers.

4.2 Design choices and elaboration of the game platform

The final design of the gaming platform aimed at providing an adaptable gaming experience. Owing to the constraints in target groups and course structure, the final design ending up leaning towards a gamified experience. The game was developed for

use on personal computer via Unity. The initial data structure aimed at structuring the game around the course requirements, translated in the form of quizzes and learning material. Interactions with the game and the platform would then provide analytics for both students and teachers.

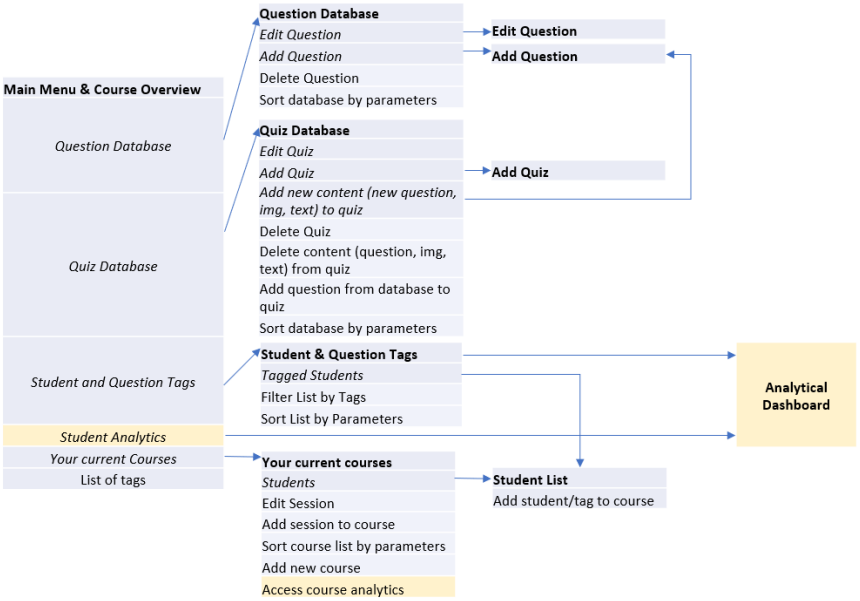

Fig. 4. Data model for FLIP2G (source: Nurogames)

A very light framing device provides a scenario, in which the student play as spy with an animal avatar, designed to be appealing to younger audiences while still relatable to older groups. Each course is presented as a mission, during which the student must go through a series of quiz-based quests and to defeat final bosses.

Fig. 5. Screenshot of student menu screen (source: FLIP2G platform, Nurogames)

In the main menu, students can access information regarding their progress and performance during each connection to the game, which allow them to monitor their progression and support self-directed learning.

The game possesses a solo mode and a collaborative mode to cover the different forms of engagement in the FC (both solo preparation at home and collaborative activities in class). In solo mode, the player has to answers questions correctly to defeat a final boss. In collaborative mode, each participant gets only part of the questionnaire (questions or answers), and participants must team up to connect the correct questions and answers.

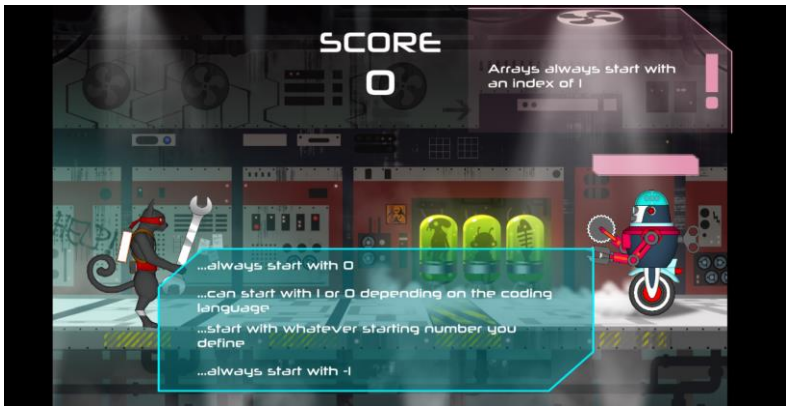

Fig. 6. Screenshot of student quiz in solo mode (source: FLIP2G platform, Nurogames)

Fig. 7. Screenshot of the student screen in cooperative mode (source: FLIP2G platform, Nurogames)

Before and during the game, participants can access the learning material to prepare for the class or to help them go through the questions.

Fig. 8. Course material access (source: FLIP2G platform, Nurogames)

Finally, the students can access a dashboard page that presents dedicated analytics regarding their progression and engagement over the course of the game. They can also access a list of their wrong answers to correct themselves if they want to take a test several times, to support a trial-and-error progression.

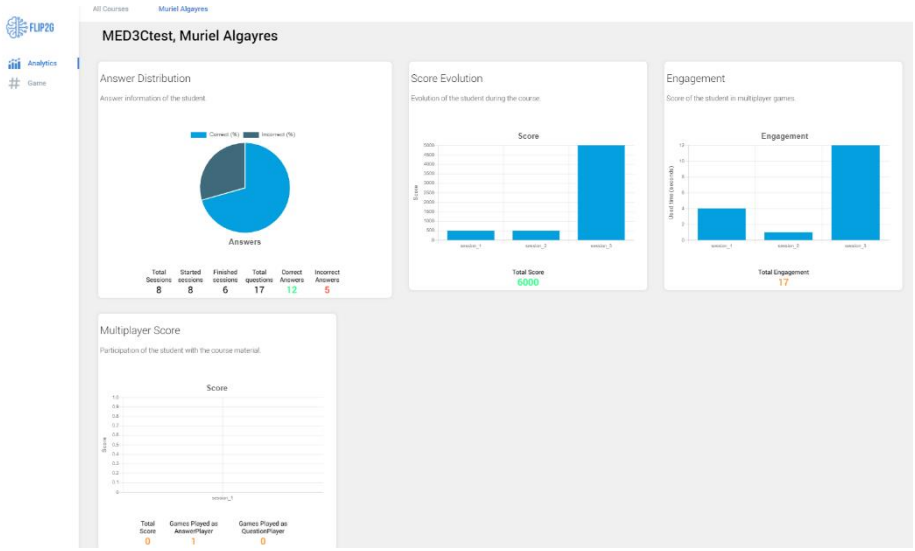

Fig. 9. Screenshot of student dashboard (source: FLIP2G platform, Nurogames)

The content of the games (questions and answers) is plugged in through the teacher interface. The teacher interface is web-based and its structure is similar to that of other VLEs, including Moodle, to facilitate implementation and adaptation of the game to any time of curriculum or student. The teacher's dashboard also includes information

regarding the performance of each student, and allows adaption of the curriculum and intervention to prevent risk of student dropout.

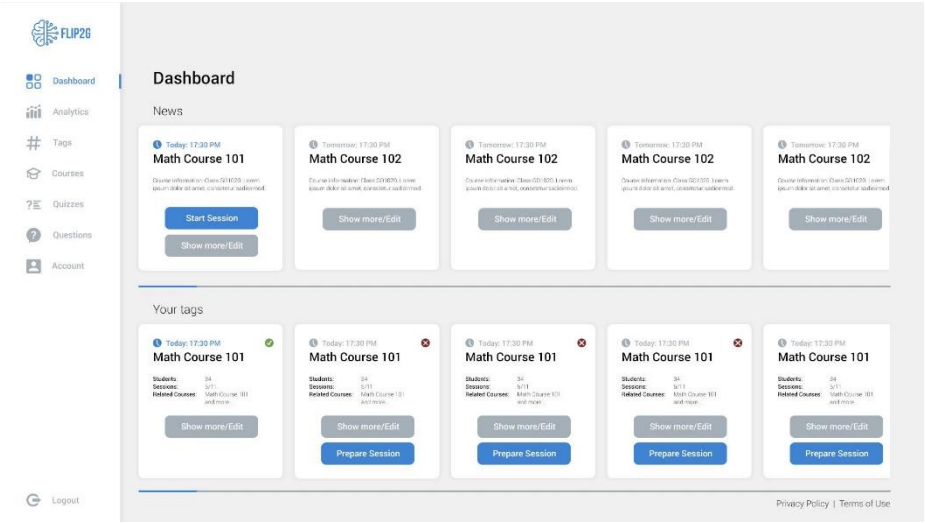

Fig. 10. Teacher's dashboard (source: FLIP2G platform, Nurogames)

Therefore, the requirements for an adaptive gaming experience and for wide flexibility got us to lean towards a gamified experience. The students benefit from a dedicated gaming platform and access to their own analytics, and the teachers can follow the evolution of their own cohorts with the possibility to identify which parts of the curriculum need revision for better engagement and which students might be at risk of dropout.

5 Discussion

Our project started with the objective of expanding and improving the FC learning experience by using the best practices of game-based learning and developing a dedicated, adaptive gaming platform.

Our literary reviews showed us that previous research had established the validity of using games in the FC, but that there was some untapped potential in trying to develop a platform that could support more closely to the needs of active learning methodologies.

During investigation into educators' needs and expectations for this game, however, we faced the challenge of needing a game that could fit the needs of a huge variety of subjects, curriculum and learning environments. This leads us to conclude that there is currently a tension between higher flexibility and adaptability of usage and more spe-

cialized gaming content. In the former case, adaptability imposes the use of gamification and/or more flexible games, whereas the latter case allows for more tailored content and game narratives, but limit its transmissibility and adaptation to other learning circumstances.

However, the final design for our gaming platform allow to cover for the wide range of experiences that structure the FC learning process. First, the student can access the learning material and play at home, then they can also train with the collaborative mode in class before consolidating their knowledge through hands-on activities, and finally they can access their performance score and analytics after class to track their progression and engage in better self-directed learning.

Although these design choices were dictated by the specific needs of the partners involved, they align with the findings of current research on the positive impact of gamification in the FC. The gamified structure supports the integration of gaming mechanics that are key to engagement in playful learning, such as clear goals, access, direct feedback, challenge, collaboration, and bespoke design framework (e.g. [40]; Huang, B., Hew, K. F., & Warning, P. (2018). Furthermore, our project also aligns with concepts of SDT [5] to support student intrinsic motivation through stimulation and sense of both competence and autonomy. Finally, our project tries to improve on previous iterations of integration of GBL in the FC by allotting specific resources to the post-class process. Our research into the literature indeed showed us that the after-class was often the neglected part of the FC [24], since focus was either on pre-class preparation, or in-class hands-on activities. By integrating the students' performance directly into the game, we aim at supporting a continuous improvement process and the capacity of students to engage in self-directed learning.

Our study into collaborative game design came yet with several limitations. The size of the focus group was limited and the participants decided by being the partners engaged in the FLIP2G project for the following pilot study into the implementation of the game. Therefore their positioning was both as practitioners and stakeholders in the implementation process, which conditioned and biased their choices and answers.

Our design choices ended up being severely constrained by the diversity of profiles that we ended up with, and forced us to choose a gamified solution that appears more limited from a narrative perspective.

As the game reaches its final stages of development, validity to its use in classroom situations remains to be evaluated in pilot trials. The model however has the potential to offer a new perspective on the integration of GBL in the FC by putting a greater attention to the analytics and analysis of the engagement process both by students and teachers. Furthermore, it might also be improve in future iterations of the game or new platforms by the incorporation of games other than simple quizzes (e.g. collaborative games, word games, crosswords, etc.). This project aims at building up and improving our understanding of the efficiency of GBL in the FC through best practices, with its full impact to be evaluated in the future through wide implementation in full cohorts of students.

6 Conclusion

The FC and GBL have been consequent developments in active learning, and recent educational developments promoting integration of 21st century skills and self-directed learning in secondary and higher education. As those two approaches are used more and more in conjunction, new challenges arise regarding the most efficient way to integrate games in the FC. Our projects aimed at designing a bespoke gaming platform that could support the whole of the FC learning experience. To that purpose, we organized a focus group of the participants in the project pilot trial. However, faced with a huge diversity of profiles and needs, we concluded that we needed a flexible structure that could adapt to these requirements, and our final design choice was to develop a gamified learning experience that prioritized scalable access to the learning material and easy implementation of quizzes, both in solo and cooperative mode. Further research perspective will aim at testing this playful learning approach over the duration of a full curriculum.

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