Enhancing education and training through data-driven adaptable games in flipped classrooms

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Abstract

The Flipped Classroom (FC) is a set of pedagogical approaches that move the information transmission out of class and exploit class time for active and/or peer learning activities. In this context, students are required to engage with pre- and/or post-class activities in order to prepare themselves for class work. The FC instruction method has already been used in conjunction with other learning strategies. This theoretical paper presents the first developmental steps of a research project, which aims at building the FC through a fully bespoke and personalized experience, by using data-driven adaptable games and problem-based learning elements to improve the learning experience. The project will develop a gaming platform that will support the whole FC in a cyclical perspective, and aims to use the resources of gamification in a more significant manner that could go beyond score tracking and badges. Moreover, the problem-based learning approach will be used to better frame the learning activities included in FCs, while learning analytics features will provide adaptable learning pathways. The potential of this approach is to build a better FC experience for all the stakeholders. Students will be given more agency to calibrate their learning experience, while educators can monitor the students' progress more effectively and adjust their learning activities accordingly. Finally, researchers will get better insight into the FC learning process, and the mechanics, which contribute to optimize the learning experience.

Keywords: flipped classroom, serious games, problem-based learning, learning analytics

1 Introduction

Active learning is now a staple of education, aiming at fostering 21st century skills. Among active learning methods, the most prevalent in education is 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." (Abeysekera & Dawson, 2015, p. 6).

The efficiency of the FC to support students' motivation and self-directed learning has been largely documented in literature reviews (e.g. O'Flaherty & Phillips, 2015), and the method is credited with success in improving students' communication skills and independent learning (Lo & Hew, 2017). Further research now investigates the potential of the FC used in conjunction with other learning methodologies, such as Game-Based Learning (GBL) and elements from Problem-Based Learning (PBL) (Klemke et al., 2018), in order to better structure out-of-class and in-class activities, increase student engagement and motivation, and better monitor student progress in FCs.

The FLIP2G project (http://flip2g-project.eu/) aims to establish a knowledge alliance between higher education institutions, schools and private companies, which will develop a new pedagogical method that combines PBL and FC with GBL. This method will be implemented as a simulation-based serious game platform that will support PBL-enhanced flipped classroom processes, adaptive pathways and educational data recording. The platform will also employ Learning Analytics (LA) features that will produce informative insights on learning process by analysing the gathered educational data. The above results aim to produce an engaging pedagogical model that employs novel technologies to foster motivation and skills development, generate adaptive learning pathways, and allow self-directed learning in education and training.

The purpose of this paper is to present the first outcomes of the FLIP2G project, namely a pedagogical model for integrating PBL with the FC instruction method, and a study on elements from serious games that can be applied in FCs. Finally, we conclude with a discussion on upcoming project outputs and milestones.

2 Background

2.1 Learning in the FC

Lage et al. defined the FC in these terms: "Inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa" (Lage et al. 2000). The FC tends to be represented as a linear process following these three phases: during the pre-class time the students prepare for the lesson, in-class they engage in group activities or discussion, and after class they complete their assignments or extend their learning. The FC presents a very specific form of didactic contract (Brousseau, 1998), in which the process of institutionalization of knowledge is self-directed by the students themselves.

However, for the purpose of a more holistic view on learning in the FC, the circular model proposed by Gerstein (2011) appears more relevant because it divides the different phases in FCs based on their pedagogical objectives rather than their chronological order. Figure 1 presents this structure.

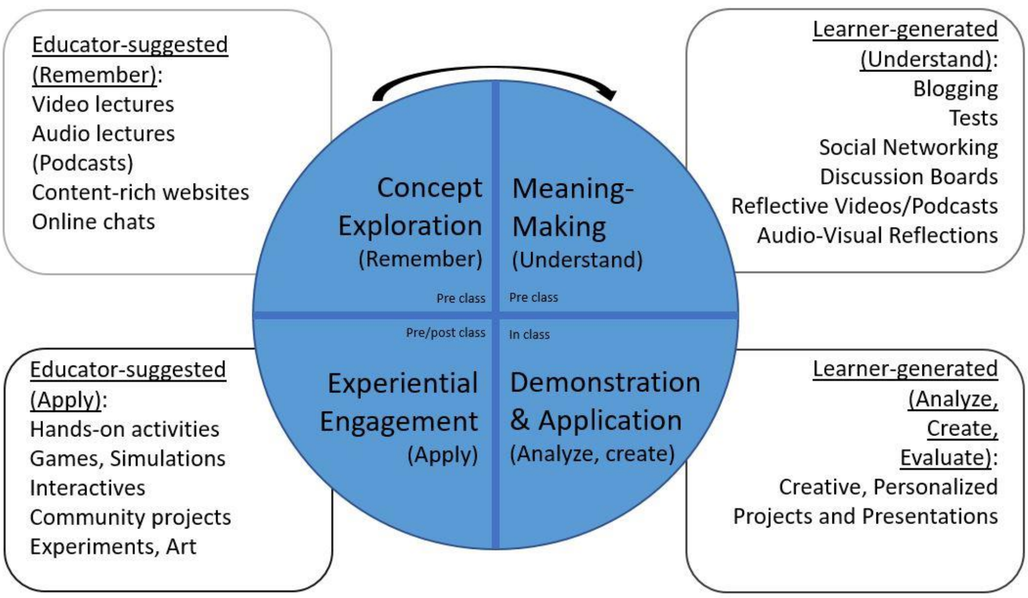

Figure 1: The Flipped Classroom Model as presented by (Gerstein, 2011).

The process begins with concept exploration. This model appears more efficient to study the FC and integrate other pedagogical tools to its implantation, as it approaches learning as a cycle and not simply a linear process. As such, the experiential engagement and concept exploration phase can overlap between the end of a FC cycle and the beginning of the next. Approaching the FC as a cycle rather than a linear process offers better perspectives to regulate its potential for self-directed learning and to integrate other methodologies in the process.

2.2 PBL and the FC

Problem-based learning (PBL) is a staple of active learning (Barge, 2010). The steps included in PBL are as follows: learners are given an ill-defined problem and they are tasked with formulating it to a concrete problem to solve. The next step is the formulation of tasks that will lead to problem solving, which should require all members to use their own knowledge and skills. Problem analysis follows, in which learners gather data to solve the problem. Once the problem has been analysed and a suitable solution devised, the learners take steps to solve the problem (Barge, 2010).

Research into blending PBL and the FC has been carried out successfully by designing learning activities in Virtual Learning Environments (VLEs), like Moodle (e.g. Triantafyllou, 2015).However, while PBL activities have been used in the FC, its integration was usually limited as an in-class activity. Clark (2015) for example used the FC methodology in secondary education as a means to support students' engagement in problem-solving activities in-class. Therefore, we believe that further application of the complete PBL model in the FC has the potential to support learning approaches through a more bespoke experience.

2.3 Learning Analytics in the FC

Another tool that has been employed for further improving FCs is the use of Learning Analytics (LA). "LA is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs." (Long & Siemens, 2011). Integration of LA in the FC goes beyond using data to evaluate the students learning process in a more reliable process compared to unreliable self-reported learning strategies (Jamieson-Noel & Winne, 2002). The purpose of LA is twofold: they are meant to support the learners learning process, but also to allow educators and researchers to intervene and modify the learner experience as needed. The goal with such interventions is to offer smart learning environments that support a fully integrated and personalized learning experience. According to Chen et al. (2016, p. 566), "…through big data and learning analytics, smart learning environments could derive new and more effective learning models by analysing the data collections of various learners and further extract valuable learning patterns, to provide suggestions and recommendations to the learners over long periods of time, possibly even during their future careers". Therefore, extensive integration of LA in the FC has the potential of reinforcing the FC methodology in the sensitive parts of the learning process, such as sustained engagement in the pre-class process, or supported self-regulated learning in the post-class phase (Herreid & Schiller, 2013).

2.4 Game-Based Learning (GBL) in the FC

Use of games in the FC

There are many precedents for effective use of Game-Based Learning (GBL) in the FC. Serious games have commonly been used during the in-class phase of the FC to engage students in active learning or collective activities. Games used for computer education and coding practice, such as HackerRank and CodinGame, are examples of this approach (Bye, 2017). Similarly, Cukurbasi and Kiyici (2018) used a combination of FC and LEGO applications to develop a mathematic algorithm instruction curriculum for the secondary school.

Serious games have also been used to support students' engagement with the learning material, and help students to practice before class. For example, *The Protégé* lets the students scaffold their engagement with the pre-class reading material by having them play as investigators in a library (Ling, 2018).

Finally, in the post-class phase, gamification appears as a common tool to calibrate the learning experience. Gamification is defined as an "…umbrella term for the use of video game elements to improve user experience and user engagement in non-game services and applications" (Deterding, 2011) and is different to GBL, which is the inclusion of games of the development of skills or training. VLEs often rely on such gaming elements (e.g. scores, levels and badges) to help students visualize their progression. Although gamification needs to be developed beyond the superficial integration of rewards-based mechanics (Becker & Nicholson, 2016), it remains a useful tool to calibrate the learning experience in the post-class phase.

Gaming Elements in the FC

Current serious games give us insights into the potential of integrating gaming elements in the FC, and the gaming elements requirements for the FC. Many games possess a component of PBL or situated learning. For example, Foldit is a game in which players can learn about protein folding and discovery of new proteins through problem-solving on the game platform (https://fold.it/portal/). Their experience is supported by rewards-based game mechanics such as leaderboards, points score, and level-up. The game Sharkworld, which supports learning of project management principles, appears also very problem-based as players are introduced to a real-world project management problems that the players have to solve by themselves (http://www.sharkworldgame.com/). The game similarly introduces rewards-based mechanics as score tabs and level-ups, and the level system is designated to frame the learning experience. Finally, the game SimPort also proposes a problem-based approach that relies on collaborative work, with each player being a team member in a construction project (Warmerdam et al., 2007). Simulation games in that regard offer great potential to support PBL applications in the FC. Moreover, Deshpande and Huang (2011) suggest through an extended state-of-the-art review that proper application of simulation games in engineering education has the potential to maximize the learning outcome, and transferability of academic knowledge to the industry. Therefore, such games may support the development of entrepreneurship skills within FC for education and training.

Furthermore, serious games rely heavily on a positive feedback loop, which supports learning through trial and error. This feature follows the gameplay model of "Objective-Challenge-Reward" (OCR) as formulated by Albina (2010). In this model, the objective needs to be clearly defined, with a clear communication regarding the conditions of success. Actions have also to be adapted to the player's level, neither too easy nor too difficult, and feedback needs to indicate clearly why the challenge was a success or a failure, so that the player can adjust their actions afterwards. Foldit, already mentioned, uses the positive feedback loop mechanic since success is built progressively, so trial and error is a viable strategy. Democracy (http://www.positech.co.uk/democracy/), a political game where the player's goal is to become President of the United States, also uses this mechanics. In this game, positive and negative decisions have a direct impact on the player's score. Players can therefore adjust their strategy in real time and experiment around potentially winning strategies. Finally, the Mathis is project (http://mathisis-project.eu/), a math puzzle game for children, shows how LA can be used to feed the positive feedback loop since the game difficulty is automatically adjusted to the player's level. Thus, the player progresses gradually and can try out different strategies to solve the puzzle and progress.

Finally, games can employ different strategies to present the players with the rules and mechanics. Within the context of the FC, guided learning could be employed to introduce learners to background knowledge. Guided learning means that the rules of the games are embedded in the play experience, usually in the form of tutorials, or that the experience is supervised by the educator. Foldit again provides an example of this approach. The game possesses extensive tutorials that explains the game mechanic and scientific principles in increasing complexity. However, some games rely more on learning by doing and anchored instruction, meaning that the players need to figure out the principles of the game as they go along, usually through trial and error. For example in the game Lightbot (https://lightbot.com/), a coding robotics game, players have to complete a series of tasks with almost no instruction for the game. They can only reach the next level by figuring out which fragments of code they need to use to get the robot to perform a specific task. Thus, although serious games can present a number of design choices and features, some gaming elements appear especially useful to implement GBL in the FC, especially the positive feedback loop and problem-solving tasks.

3 Presentation of the theoretical model

The FLIP2G project endeavours to develop a theoretical model that will combine PBL elements, LA and GBL in the FC. Our objective is to develop a gaming platform that will allow students to undergo a personalized self-regulated learning experience, and facilitate the work of educators by providing them with an accessible interface and data to support calibration of the curriculum. To develop this model, we have taken the FC cycle by Gerstein (2011) as a foundation stone, and integrated the aforementioned approaches. This model consists of three levels to the learning experience: the learning activities, data generation, and LA. Figure 2 illustrates this three-tier model.

On the first level, learning designers develop specific activities. These activities are framed by the PBL pedagogy and may be game-based learning activities or contain gamification elements. Such activities are developed in "plan-design-implement" cycles, and may be adjusted based on the findings produced on the LA level (third level of the model).

On the second level of the model, the designed learning activities are applied and implemented in consecutive FC cycles. Each phase in such cycles generates its own data in online environments through students' engagement with the online resources, online exchanges and productions.

On the third level, educational data produced on the second level is processed through LA to provide formative and summative feedback to students and educators, and allow educators to adjust the learning process and the curriculum.

The following sections will present an overview of each step of this new FC cycle on the second level of the model.

3.1 The experiential engagement phase

The experiential engagement represents both the conclusion of a FC circle and the introduction of the next one. During this phase, students can engage in online discussions, play a video game in pairs, or complete their learning by out-of-doors activities, e.g. visiting a museum. For a PBL approach, students can be introduced to an ill-defined problem through video lectures and tutorial. In the final phase of the PBL, this phase will also be when students evaluate a solution to the problem by running experiments and surveys.

3.2 The concept exploration phase

This phase is when the students start engaging with learning materials. From a PBL perspective, this is when students groups try to understand and analyze the problem. They can build their knowledge by classic means of video lectures, podcasts, and textbooks or by discussing with their teachers. During this phase, the use of games can be a very efficient means to engage with the problem, e.g. with historical or simulation games. Engagement with learning material during the concept exploration phase can be supported by peer learning activities such as discussions, debates and concept mapping activities.

3.3 The meaning making phase

The meaning making phase is the phase of problem analysis for a PBL approach. This phase is supported by hands-on activities and summative assessments: discussions in class, writing essays and reports, develop wikis or online material.

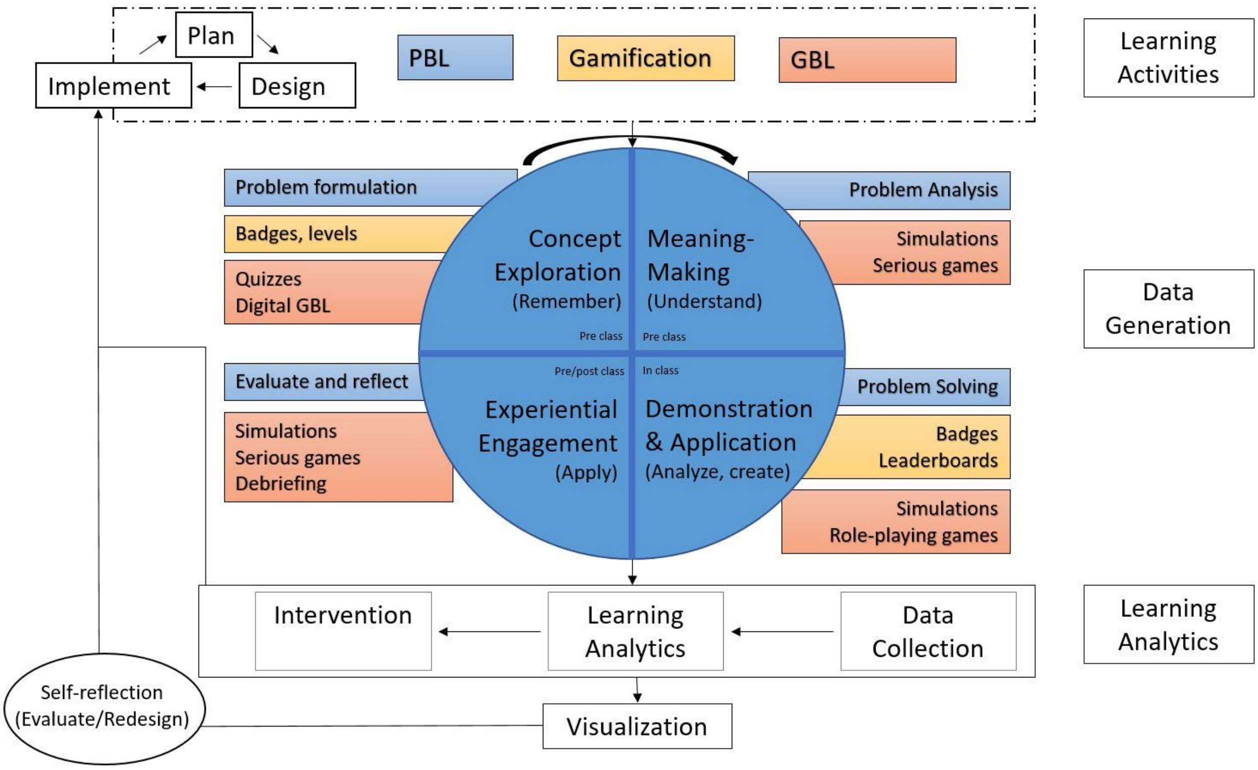

Figure 2: The proposed three-tier educational model

3.4 The demonstration and application phase

Finally, the demonstration and application phase is when students design and implement a solution for a PBL activity. They can work online or offline, as a whole group or in smaller units, each working separately before bringing all elements of a solution together. Students can also design their own online portfolio and build on social interactions and exchanges online.

4 Future Development

In the previous section, we presented a pedagogical model applying the PBL approach to the FC learning cycle in order to better frame and design learning activities for FCs. Moreover, this model takes into consideration the integration of game-based learning and serious games elements in order to support skill development and motivation in FC. Finally, the model accommodates the use of LA in order to provide data-driven and adaptable learning pathways for learners in FCs.

As a first step, we have investigated current serious games in order to identify which gaming elements could be integrated in PBL-led FCs. The next step will be now to develop a simulation-based serious game platform, which will support PBL-enhanced flipped classroom processes, adaptive pathways, and educational data recording. This platform is going to be employed and evaluated for designing and implementing learning modules on secondary and higher education and in training. For developing such modules, we are going to apply a learning design approach with the aim to produce learning scenarios that can be transferred to various contexts.

A major part of the future development in the project is the LA features that the game platform is going to employ. The next milestone in this regard will be a detailed description of possible learning activities in each phase of the FC, the data that can be produced during these activities, and the LA that will be applied in such data in order to produce informative insights on learning processes. Such insights will be then used to adapt pathways in order to adjust learning to individuals, and also to provide formative and summative feedback to learners and educators. The educators will then be able to use this feedback to adjust and redesign learning activities in order to better facilitate their teaching.

5 Conclusion

We have seen that the FC has already been used in conjunction with other learning strategies. GBL and simulations have been used in the FC with efficiency, but usually at a targeted time of the FC process, either for pre-class preparation or as an in-class activity. Some elements of PBL (especially for problem formulation and problem-solving activities) have been found in the FC as well. Furthermore, while the educational potential of LA is also established, its complete integration through smart learning environments is still an expanding field.

Our model aims at building the FC through a fully bespoke and personalized experience, by using various tools to improve the learning experience. It aims at building a gaming platform that swill support the whole FC in a cyclical perspective, rather than using games in a punctual manner. Similarly, such a platform could use the resources of gamification in a more significant manner that could go beyond score tracking and badges.

The potential of this model is to build a better FC experience for all the stakeholders. Students are given more agency to calibrate their learning experience. Educators can monitor the students' process more effectively and adjust their learning activities accordingly. And finally, researchers will get better insight into the FC learning process and the mechanics which contribute to optimize the learning experience.

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