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# ENHANCING EDUCATION AND TRAINING THROUGH DATA-DRIVEN ADAPTIVE PROBLEM-BASED FLIPPED CLASSROOMS WITH GAMIFICATION

BY
MURIEL ALGAYRES

DISSERTATION SUBMITTED 2022

AALBORG UNIVERSITY
DENMARK

# ENHANCING EDUCATION AND TRAINING THROUGH DATA-DRIVEN ADAPTIVE PROBLEM-BASED FLIPPED CLASSROOMS WITH GAMIFICATION

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Dissertation submitted

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# CV

Muriel Algayres received a MA in Medieval History from La Sorbonne in 2003. She completed a MA in educational research and didactics from Cergy – Paris Seine University in 2018. She taught Humanities for several years in secondary and undergraduate level while designing her own serious games in form of narrative scenarios for educational roleplaying. She was appointed a PhD fellow in the Department of Media Technology at Aalborg University Copenhagen, Denmark in March 2019.

# ENGLISH SUMMARY

The purpose of this PhD thesis is to investigate the potential of expanding the Flipped Classroom model by structuring it around Problem-based learning and supporting it with Learning Analytics and Gamification. We considered if we could build a pedagogical model that would support student performance and motivation while improving on the Flipped Classroom model. We evaluated this model and, in addition, tested it under different modes of eLearning delivery.

Active learning and the principles of Flipped learning, valuing a student-centered, hands-on, collaborative approach, have become more and more commonplace as challenges in education evolve with massification of teaching and increased reliance on technology. The Flipped Classroom was one of the foremost pedagogical models that supported these changes but there has been little evolution outside of the core tenets of the models. As the need for stimulating eLearning and flexibility in learning are ever increasing, there is an incentive to improve on Active learning and the Flipped classroom model to support its use in the most efficient way.

This investigation was conducted in different phases: an analysis of the Flipped Classroom model, the design of the pedagogical model from early drafts to the final version incorporating a complete educational framework, implantation and testing of the model, and adaptation to different modes of online learning. Implementation and testing were conducted over two semesters in Spring and Fall 2021, using mixed methods to map the students' learning experience and evaluate the pertinence of the proposed pedagogical model.

The findings indicate that the data-driven problem-based Flipped Classroom, supported by gamification, is a relevant educational model that is flexible and can easily be adapted for different subjects and online learning contexts, with the potential to support more endeavors into transdisciplinary learning. It emphasizes that students benefit from consistent preparation outside of class, and dynamic interactions inside of class, but that they are also appreciating more and more the flexibility that goes with hybrid and blended modes of learning. It calls to attention the potential to use Flipped learning in a context of increased need for flexibility, and that the core issues of technological stability, clear objectives and sustained motivation remain the main challenges moving forward.

# DANSK RESUME

Formålet med denne ph.d.-afhandling er at undersøge potentialet i at udvide Flipped Classroom-modellen ved at strukturere den omkring problembaseret læring og støtte den med Learning Analytics og gamification. Vi overvejede, om vi kunne opbygge en pædagogisk model, der ville understøtte elevernes præstationer og motivation, samtidig med at vi forbedrede Flipped Classroom -modellen. Vi evaluerede denne model og testede den desuden under forskellige former for eLearning-levering.

Aktiv læring og principperne for Flipped Learning, der værdsætter en elevcentreret, praktisk og samarbejdsorienteret tilgang, er blevet mere og mere almindelige i takt med, at udfordringerne inden for uddannelse udvikler sig med massificeringen af undervisningen og den øgede afhængighed af teknologi. Flipped Classroom var en af de vigtigste pædagogiske modeller, der understøttede disse ændringer, men der har kun været lidt udvikling ud over de centrale principper i modellerne. Da behovet for stimulerende eLearning og fleksibilitet i læring er stadig stigende, er der et incitament til at forbedre aktiv læring og Flipped Classroom-modellen for at støtte brugen heraf på den mest effektive måde.

Denne undersøgelse blev gennemført i forskellige faser: en analyse af Flipped Classroom-modellen, udformning af den pædagogiske model fra tidlige udkast til den endelige version, der omfatter en komplet uddannelsesramme, implementering og afprøvning af modellen og tilpasning til forskellige former for online-læring. Implementering og afprøvning blev gennemført over to semestre i foråret og efteråret 2021 ved hjælp af blandede metoder til at kortlægge de studerendes læringsoplevelse og evaluere relevansen af den foreslåede pædagogiske model.

Resultaterne viser, at det datadrevne problembaserede Flipped Classroom, understøttet af gamification, er en relevant pædagogisk model, der er fleksibel og let kan tilpasses til forskellige fag og online læringskontekster, med potentiale til at støtte flere bestræbelser på tværfaglig læring. Det understreges, at de studerende har gavn af konsekvent forberedelse uden for undervisningen og dynamiske interaktioner inden for undervisningen, men at de også i stigende grad sætter pris på den fleksibilitet, der følger med hybride og blandede læringsformer. Den gør opmærksom på potentialet i at anvende Flipped Learning i en kontekst med et øget behov for fleksibilitet, og på at de centrale spørgsmål om teknologisk stabilitet, klare mål og vedvarende motivation fortsat er de største udfordringer fremadrettet.

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My thanks also to my PhD supervisor, Olga Timcenko. Her advice and support contributed immensely to the conduct of this PhD. She allowed me to explore my own ideas for the project and her encouragements in the trying final months gave me the necessary confidence in my work and myself to get to the finish line.

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*Muriel Algayres*

*September 2022*

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This dissertation is separated in two parts. The first part consists of six chapters. Chapter 1 provides an overview of the structure of the dissertation and mentions the papers authored during the 3-year period of this PhD project. Chapter 2 introduces the context and motivation for this project, while Chapter 3 presents relevant background work. Chapter 4 provides a reflection on the methodological approach, and Chapter 5 summarizes the main contributions. Finally, Chapter 6 discusses the results of this project and provides directions for future work.

The second part contains eight scientific papers that are representative of the research carried out in this project. In the following, section 1.1 provides a list of the included papers and section 1.2 mentions other papers, which were authored during this PhD project but are not included in this dissertation.

## 1.1. PAPERS INCLUDED

In this dissertation, the included papers comprise two journal papers and six conference papers. Each paper will be identified by a designated roman number.

Paper I. Algayres, M. G., & Triantafyllou, E. (2020). Learning analytics in flipped classrooms: a scoping review. *Electronic Journal of e-Learning*, 18(5), 397-409. *Journal article, published*

Paper II. "Data-driven active Problem based learning in the Flipped Classroom supported by gamification". Educational Technology and Development (submitted for publication)
*Journal article (submitted for publication)*

Paper III. Algayres, M., & Triantafyllou, E. (2019). Combining game-based learning and the flipped classroom: a scoping review. In *European Conference on Games Based Learning* (pp. 823-XII). Academic Conferences International Limited. *Conference proceedings paper presented at ECGBL 2019, October 2019, Odense, Denmark.*

Paper IV. Algayres, M. G., Shekhawat, Y., Timcenko, O., Zotou, M., Tambouris, E., Malliarakis, C., Dermentzi, E., Lopez, R., Jatten, E. & Tarabanis, K, (2019), Enhancing education and training through data-driven adaptable games in flipped classrooms, in *Gaming Elements and Educational Data Analysis in the Learning*

*Design of the Flipped Classroom*. Triantafyllou, E. (red.). Aalborg Universitetsforlag, s. 25-39 39 s.
*Conference paper presented at EC-TEL 2019, September 2019, Delft, Netherlands (GALE workshop).*

Paper V. Algayres, M. G. & Triantafyllou, E., (2020) An educational model for integrating game-based and problem-based learning in data-driven flipped classrooms, Emerging Technologies for Education - 4th International Symposium, SETE 2019, held in Conjunction with ICWL 2019, Revised Selected Papers.
*Conference paper presented at ICWL 2019, September 2019, Magdeburg, Germany (SPeL workshop).*

Paper VI. Algayres, M. G., Triantafyllou, E., Werthmann, L., Zotou, M., Tambouris, E., Malliarakis, C., Dermentzi, E., Lopez, R., Jatten, E. & Tarabanis, K., (2021), Collaborative game design for learning: the challenges of adaptive game-based learning for the Flipped Classroom. *Interactivity and Game Creation: 9th EAI International Conference, ArtsIT 2020, Aalborg, Denmark, December 10–11, 2020, Proceedings*. Brooks, A., Irene Brooks, E. & Jonathan, D. (eds.). Springer, Vol. 367. p. 228-242 (Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering)
*Conference proceedings paper presented at ArtsIT 2020, December 2020, Aalborg, Denmark.*

Paper VII. Development and use of a Playful Learning Observation Tool (PLOT) for Active Game-based Learning in Physical Classroom Situations Algayres, M. G., Timcenko, O., Triantafyllou, E., ECGBL 2022 (to be published)
*Conference proceedings paper to be presented at ECGBL 2022, October 2022, Lisbon, Portugal.*

Paper VIII. From flipped to remote to hybrid: transformation of a game-based flipped classroom during the Covid-19 pandemic Algayres, M. G., Timcenko, O., Triantafyllou, E., ECEL 2022 (to be published)
*Conference proceedings paper to be presented at ECEL 2022, October 2022, Brighton, UK.*

## 1.2. PAPERS NOT INCLUDED

Online environments for supporting learning analytics in the flipped classroom: a scoping review Algayres, M. G. & Triantafyllou, E., 2019, Proceedings of the 18th European Conference on e-Learning (ECEL 2019). Ørngreen, R., Buhl, M. & Meyer, B. (red.). Academic Conferences and Publishing International, s. 16-23 ( Proceedings of the European Conference on e-Learning ). (Conference paper expanded and published as journal paper)

Combining the flipped classroom and simulation games in engineering education: a methodological survey Algayres, M. G. & Triantafyllou, E., 2019, Varietas delectat... Complexity is the new normality: Proceedings SEFI 2019 · SEFI 47th Annual Conference · Budapest, 16-20 September, 2019. SEFI: European Association for Engineering Education, s. 83-92 (Published, peripheral to main subject of thesis)

# CHAPTER 2. INTRODUCTION

This dissertation focuses on the Flipped Classroom model and how it can be implemented and expanded to support student motivation and engagement. In this section, the characteristics of this pedagogical model are presented, as well as convergence of the Flipped Classroom and Problem-Based learning methods. Evolution in eLearning and blended learning are also addressed. Finally, motivation for researching this specific pedagogical model is discussed.

## 2.1. THE FLIPPED CLASSROOM AND FLIPPED LEARNING

Education has undergone major changes following the massification of education in industrialized countries, as well as the digital and technological revolution. This rapid paradigm shift encouraged student-centric learning models to support active and self-directed learning, as well as sustained motivation and engagement.

Active learning changes "the focus of learning from passively receiving content information to diligently participating in learning activities" (Frey, 2018). In that regard, the concept of the inverted classroom, where events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa" (Lage, Platt and Treglia, 2000) appeared as a concrete application of the principles of active learning. The Flipped classroom (FC), defined as "an instructional strategy (…) delivering the lecture-based content online and (…) practical exercises in the classroom, encouraging support from educators and other students" (Bergman and Sams, 2012), became the most emblematic pedagogical model associated with this approach. By extension, the "Flipped learning" terminology has become more widely used than "inverted classroom" to refer to the same approach. A google trend research shows that, if the three denominations coexisted at the same level at their inception, since the 2010s "flipped classroom" has dominated at a ratio of 2:1 compared to "flipped learning" while "inverted" classroom or "inverted" learning have fallen in disuse.

There were however considerable challenges in trying to change pedagogical models in radical ways from a lecture-based traditional content to student-centered active or flipped learning. Early studies in flipped learning focused first and foremost on students' resistance and challenges, "because it requires that they do work at home rather than be first exposed to the subject matter in school" (Herreid & Schiller, 2013) The quality of flipped learning is negatively impacted by student being under-prepared, as well as educators struggling to integrate technology and online resources effectively. Similarly, Rahman et al. (2021), made a comprehensive review of the obstacles to flipped learning. They emphasized the following issues which can lead to a negative *a priori* regarding the educational shift:

- Technology: insufficient accessibility to technology, digital literacy in learners and cost of implementation in educators.

- Learners' hesitancy: reluctance to adapt to a new model, personal work and family related time constraints, lack of responsibility in learning

- Educators' hesitancy: increased workload and training development, lack of reliable technology, changing role from lecturer to facilitator

Therefore, research into the Flipped classroom (FC) tried to address these issues while gathering evidence of its efficiency. For example, Abeysekera and Dawson (2015) propose that due to the active participation of students, "[learning] environments created by the FC approach are likely to satisfy student needs for competence, autonomy, and relatedness and, thus, entice greater levels of intrinsic motivation". (Abeysekera & Dawson, 2015) Similarly, Herreid and Schiller (2013) through a survey of over 15,000 members of the National Centre for Case Study Teaching, listed the advantages of the FC methodology in terms of flexibility, student engagement and autonomy, and educators being able to support their students more closely. For the Flipped Classroom Network (FLN), there are four key features in the flipped classroom pedagogical model (FLN, 2014; Bergman & Sams, 2012):

(1) **F**lexible environment: time, schedule and physical space can be adjusted to different students and activities.

(2) **L**earning culture: focus on a student-centered approach that encourages autonomous learning in students and active mentoring in educators.

(3) **I**ntentional content: educators adapt the content of their classes to maximize active learning strategies. They can also adapt content to support at-risk student or encourage proactive learners.

(4) **P**rofessional educator: educators play a different but crucial role in accompanying students to autonomy, providing them with feedback and constructive criticism.

The main principles of the Flipped Classroom – e.g., that optimizing class time for active learning and hands-on activities is beneficial to students, that educational content that can be learned online should be made accessible ahead of class and not saturate lecture time – have become more and more widespread in the field of education, technology, and active learning. Research in the Flipped Classroom model, though, is both an expansive field and a domain where little is known beyond surface level application of the fundamental pillars of F-L-I-P. The literature leaves a lot of space for further development of the Flipped Classroom model, in terms of expanding it with Active Learning methodologies and increasingly varied forms of technology.

The Problem-Based Learning model is an example of an active learning methodology that has both been established for a long time and benefitted from the added input of the Flipped Classroom and stands to contribute to the development of Flipped Learning even further.

## 2.2. THE AALBORG PBL MODEL

The purpose of this PhD was to improve and expand the application of the FC through the integration of the best practices of active learning. We investigated improvements that could be carried by Game-based learning (GBL) and gamification in the FC, as well as use of Learning Analytics (LA). The objective of the FC includes encouraging students to monitor their own progression. Therefore, with rewards-based gamification, it is implicit that the gamified elements of badges and leaderboards can support students to track their progress (Latulipe, Long & Seminario, 2015). Similarly, LA supports the collection and analysis of data regarding learners and might prove crucial in further developments of the FC. LA can help students track their progression, as well as educators who teachers can in turn use this information to make informed pedagogical decisions and interventions (Van Leeuwen, 2018).

However, the Aalborg PBL (Problem-based learning) model contributed the most to the objective of expanding the FC. Problem-based learning activities have been cited as a form of active learning appropriate for the FC (e.g., Song et al., 2017). Problem-solving allow students to use the knowledge they acquired out of the classroom, allowing for collaborative learning and the creation of communities of peer learners (Abeysekera & Dawson, 2015). Research has shown that the FC combined with the problem-solving strategy was more effective than eLearning or learning with PBL alone (Chiang, 2017)

The Problem-Based Learning (PBL) pedagogy has been applied at Aalborg University since its establishment in 1974 (Barge, 2010). Furthermore, research into blending problem-based learning and the FC has also been carried out successfully, through the evaluation of virtual learning environments (VLE), like Moodle (Triantafyllou, 2015) and the use of learning design methodology (Triantafyllou, Kofoed, Purwins, & Timcenko, 2016) to improve course delivery and support educators' self-reflection. Research in problem-based learning at Aalborg University has also integrated the latest development in game-based learning using game design and production as a core for the experiential learning experience (Schoenau-Fog, Reng & Kofoed, 2015).

Although there is potential to use PBL in the FC, as well as new technologies such has GBL and LA, there is still little investigation in building a comprehensive model supporting the best practices of active learning together. Similarly, there is very few educational models that are built as holistic frameworks for implementation of the FC, including activities and use of technology. This PhD research aimed at expanding the

FC model and providing an answer to these issues. However, as for many educational projects, this experimentation and our established uses of online learning activities had to be drastically altered during COVID-19.

## 2.3. LEARNING EXPERIENCES DURING COVID-19

The novel coronavirus (COVID-19) was declared a global pandemic on 12 March 2020. The virus spread rapidly worldwide, and prevention of contamination quickly became a global issue. The WHO recommended several public health and social measures (PHSMs) to suppress SARS-CoV-2 including but not limited to personal protective measures (e.g., physical distancing, hand hygiene, mask-wearing); environmental measures (e.g., cleaning, disinfection, ventilation); and physical distancing measures (WHO, 2021). High Education Institutions (HEI) were largely affected by the social distancing measures, with many schools and universities having to move their teaching online. By 2022, 92% of the HEIs in Europe offered a form of remote teaching and learning (Jensen, Marinoni, & Van't Land, 2022). While online education had been used before and widely tested for its flexibility and convenience, this sudden shift was dubbed Emergency Remote Teaching (ERT) owing to the specific time and resources constraints that triggered its use during COVID-19 (Hodges et al., 2020). Institutions adapted to the new context, but rapid changes and uncertainty had a huge impact on both educators and students, who frequently reported increased stress, risk of depression, lack of motivation and difficulty focusing (Birmingham et al., 2021). As restrictions were lifted, the possibility of returning to campus was seen as desirable both for social interactions and improvement in education quality.

As of 2022, the outcome of the crisis is still contrasted. HEIs showed resilience in adapting to ERT and used digital tools like never before. On the other hand, issues regarding digital literacy and accessibility were noted, from disenfranchised students to educators struggling with online and remote teaching, as much as 75% of staff in 1 out of 4 institutions reported having never worked with eLearning before. (Jensen, Marinoni, & Van't Land, 2022) Digital infrastructures and tools were reinforced during the pandemic, and reliance on these tools can be expected to increase.

Aalborg University followed the government-mandated restrictions by sending students home by the 13th of March 2020. (DP, 2020) Teaching was conducted exclusively online until students were gradually allowed to renter campus at the end of Spring 2021. The Fall semester of 2021 marked the full return to campus with physical classes being allowed again. However, due to students having sometimes to isolate or being sick, forms of hybrid learning remained in effect, with lectures being recorded and students being allowed to participate to the class online when they could not join physically. Our model of expanded FC was set to be tested during the year 2021, in the Medialogy course at AAU. Media Technology is an education that focuses on research and development, which combines technology and arts and looks

at the technology behind areas such as advanced computer graphics, games, electronic music, animations, interactive art, and entertainment. Due to these circumstances, the FC model was adapted to Emergency Remote Teaching and hybrid learning, which allowed us to explore various forms of eLearning, and how principles of flipped learning could be adapted to various contexts and technological environments.

The aim of this PhD study was to improve on the FC model by supporting this pedagogical approach with Active Learning best practices especially PBL, and relevant technological support through gamification and LA. Research has shown that the FC tend to be well-received by students, but that support is needed to make the methodology really engaging and to support the technological shift for both students and educators. (Herreid & Schiller, 2013) Based on findings regarding the evolution of the FC and the advantages of the PBL model which AAU applies in all its programs (Barge, 2010), this PhD project built an original FC pedagogical framework integrating these components and applied the model among Medialogy students over the two semesters of 2021. Evaluation of the model followed two directions: first, the model was evaluated for its potential to support student motivation, engagement, and performance, and then, the pertinence of dedicated technological tools and the adaptation of the FC to other modes of online delivery (ERT, hybrid), was also investigated.

The following section reviews research on these three fields, namely 1) the FC model and its evolution, 2) educational frameworks for active learning in the FC using learning design and 3) evolution of educational technologies for online content delivery and eLearning.

# CHAPTER 3. BACKGROUND

This chapter provides an overview of background work on the three research directions of this PhD project, namely on 1) the FC model and its evolution, 2) educational frameworks for active learning in the FC using learning design and 3) evolution of educational technologies for online content delivery and eLearning.

## 3.1. THE FLIPPED CLASSROOM MODEL AND ITS EXPANSION

The Flipped classroom methodology has become a major educational development during the past decades, with increased focus on the adjacent, broader field of Flipped Learning (FL). FL focuses on articulating each phase of the FC, and improving the students practice and interaction in the classroom, especially through collaborative work and organization of the learning space to support dynamic and interactive interactions (Hwang, Lai & Wang, 2015). Flipped Learning therefore expands the scope of the FC by creating a framework to enable other instructional strategies such as project-based learning, game-based learning, or any other active learning strategies, as well as effective application of education technology. (FLIG, 2017)

However, for the purposes of this PhD, I retained the notion of the FC defined as "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) Although the aim of the PhD is to investigate a flipped approach within a wider context and could have used the wider umbrella term "Flipped learning", our purpose was to focus on expanding and implementing the FC as a pedagogical model, and therefore it made sense to use the "Flipped Classroom" terminology. Furthermore, although FL and inverted learning have their own uses, "Flipped Classroom" is the more established term, especially in literature reviews.

Recent literature reviews confirm solid interest in the FC and its implementation. Lo and Kew (2017) in their review of the FC in Secondary education, reported better or equal results to traditional classroom, and positive feedback about accessing videos online, having better interactions with educators and peers, and applying knowledge for problem solving. Similarly, the systematic review conducted by Akçayır and Akçayır (2018) presented positive outcomes for the FC model, with more than half of the studies (52%) reporting improved learning performance of students, and moderate number of studies underlining increased student satisfaction (18%) and level of engagement (14%). Finally, Turan and Akdag-Cimen (2020) systematic review of the FC applied to English as a foreign language education, stated that most studies showed

enhanced engagement of learners, learners' speaking skills, peer interactions, and learning achievement of learners.

However, there has been little investigation into expanding the FC model. Integration of other modes of active learning is of course present in many studies, but it appears it rarely, if ever, was approached as the main theme and in a comprehensive manner. This PhD project focused on the potential to integrate PBL, GBL and LA elements in the FC. Previous research indicated that there was potential to cross over the best practices of these methodologies with the FC. For example, Chis and al. (2018) tested a FC-PBL model which "makes use of learning technologies and supports authentic learning in terms of authentic context, multiple perspectives through teamwork and collaboration". Their study boasted a 26.56% increase in the assessment results for the FC-PBL.

Integration of Game-Based learning and gamification, i.e., integration of "video game elements to improve user experience and user engagement in non-game services and applications" (Detering, 2011) was an early feature in several FC studies. Gamification would be implemented in the form of badges or accomplishments visible in the virtual learning environment to motivate pre-class preparation, allowing students to monitor their progress and visualize their learning goals (Matsumoto, 2016). Gaming elements can also be integrated during the class time as in-class activities. Latulipe, Long, and Seminario (2015) for example, used questions tokens to encourage their learners to try and find answers by themselves before asking the teachers (study groups retaining all their tokens would gain bonus points). Playful competition through beginning of class quizzes can also be favored, especially with clickers and/or an online quiz (e.g., Kanbul & Ozdamli, 2018). This aligns previous research supporting the use of gamified quizzes as an efficient tool for student engagement (Kay & LeSage, 2009).

LA have also entered the FC in recent years. Indeed, the massive generation of data provided by Learning Management Systems provides huge opportunity for analysis that can inform on learners, their behaviour and progress, and allow educators to monitor their progress more closely and make informed decisions (Long & Siemens, 2011). Lam, Lau, and Chan (2019) thus advocated extended use of LA in the FC while pointing out the limitations of current Learning Management Systems (LMSs) to provide a valuable use of LA in the FC.

Finally, some research incorporated several methods and worked towards expanding the FC model. Klemke and al. (2018) developed a flipped MOOC model integrating game design as a problem-based learning activity and LA. Uskov and al. (2017) provide a list of arguments supporting, in the same manner, the integration of GBL and LA in smart learning environments for the FC.

In this PhD project, the Flipped Classroom was used as the core active learning methodology in Medialogy classes. Research into blending problem-based learning and the FC has also been carried out at AAU before (Triantafyllou, 2015). Both PBL and the FC are student-centered instructional approaches. The Aalborg model promotes collaborative work and self-directed learning, and the FC also encourages autonomy and self-directed learning skills. Finally, both represent a paradigm shift for both students and educators. Students are meant to study individually and to take ownership of the learning process and educators transition from the role of lecturer to that of tutor who accompanies and supports the learning process.

As such, although the field is relatively recent, our background research indicated that there is potential to integrate the PBL model in the FC, in a holistic approach supported by LA and gaming elements. This PhD research aimed to determine the most efficient way to integrate these elements and best practices into a cohesive model and is inscribed in the research conducted with PBL and the FC at Aalborg University, as well as aiming to contribute to the current state-of-the-art of the FC. By analyzing previous research into expanding the FC with LA and GBL, the first step in the PhD study was to define which elements would be used to expand the FC model and design a dedicated pedagogical model for the FC.

## 3.2. LEARNING DESIGN AND EDUCATIONAL FRAMEWORKS FOR THE FLIPPED CLASSROOM

With educational challenges becoming more complex and increased need to rely on technology, models to frame the learning experience and support educators in choosing the best tools and activities have also become more common. Educational frameworks can be defined as a research-informed model that provides a foundation to enhance the learning outcomes, help instructors align learning goals with classroom activities, create motivating and inclusive environments, and integrate assessment into learning." (Ambrose et. al., 2010) The purpose of learning framework if to provide structures for continual student development, that inform students of how to apply the skills and knowledge their learn in a meaningful and organized way. (Barr & Tagg, 1995)

Such frameworks make sense for the implementation of the FC as a pedagogical model, since it requires multiple tools, activities and learning material that need to be prepared, organized, and presented in a cohesive way. Furthermore, a dedicated educational framework can help address some issues of the FC, such as generalizability, i.e., "a need for more flipped classroom research which focuses on numerous course implementations, to see whether the model is suitable for large-scale implementation." (Akçayır & Akçayır, 2018) as well as the necessity for educators to "know how the method works and what should be accomplished prior to the start of flipped courses". (Turan & Akdag-Cimen, 2020)

Pedagogical models and educational frameworks have been used in research to map the learning experience in the FC. For example, Nechodomu, Falldin, & Hoover (2016) built a model that paralleled activities in the FC with Bloom's taxonomy, to illustrate that in-class time should be given to students to focus on practice and reflection (higher levels in Bloom's taxonomy). The Experiential Learning Cycle model devised by Kolb (2014) also inspired several FC pedagogical models, especially the FC wheel model in four steps elaborated by Gerstein (2011) which became a central point of reference over the course of this PhD study. Other examples include the self-regulated learning circular model by Blau & Shamir-Inbal (2017) which emphasizes individual and collective regulation practices and a dual model presented by Lo & Hew (2017) which visualizes the articulation between out-of-class and in-class activities.

Finally, Learning Design also appeared as a prime method to optimize the development of pedagogical frameworks and learning activities in the FC. Learning Design is defined as "the learning activities and the support activities that are performed by different persons (learners, teachers) in the context of a unit of learning (e.g., a course, a lesson or any other designed learning event)." (Koper, 2006) Learning Design was applied to the FC in Aalborg Medialogy department and studied in Triantafyllou et al. (2016). Learning Design was used to describe the structure of teaching and learning that would follow the FC structure (as regard in and out-of-class sessions in particular), inform the decisions taken in the course design, as well as adapt the learning sessions all through the semester. The application of this methodology over three semesters of statistics course for undergraduates revealed that it encouraged educators to reflect on their own practice, and that the FC enabled them to get valuable feedback from their students. The most common framework for Learning Design is defined in the Larnaca Declaration on Learning Design (Dalziel et al., 2016) This declaration defines the core concepts of Learning Design (guidance, representation, sharing), and the development of a Learning Design teaching cycle by three central steps: planning activity, design core-learning concepts, and implement activity.

Therefore, there were precedents to building educational frameworks for the FC, especially through the Learning Design approach, although no educational model had tried to sort out the best practices of Active Learning methodologies in one cohesive model. I considered Learning Design should be used as a framework for the design of learning activities in the FC as it seemed the most flexible model, that had already been used successfully to design meaningful learning experiences. Thus, a central goal of the PhD was to design a new pedagogical model for the FC and present it as a fully developed educational framework. This pedagogical model and educational framework would enhance and support the FC through PBL with support of gamification, as well as LA to improve the learning experience for both learners and educators. Learning Design, in that regard, seemed to have the better potential to support the development of the educational framework and learning activities.

## 3.3. ICT-BASED LEARNING AND MODES OF ONLINE DELIVERY

In the last decades, online teaching and research in eLearning have been increasingly developing fields. The rapid development in ICT has provided new possibilities to integrate digital technologies into education and thus enhance teaching and learning. Learning technologies ranging from cognitive tools to more sophisticated and complex environments, such as Learning Management Systems (LMSs), Virtual Learning Environments and the recent Massive Open Online Courses (MOOC), generate large amounts of educational data that can provide the basis for efficient implementation of LA.

Traditional teaching is conceptualized as face-to-face, "seat time" in person with the instructor, but use of ICT has become extremely diverse, and presented under various terminologies. Technology-Enhanced Learning incorporates IT tools to traditional delivery (e.g., a LMS to access learning material and computerized homework), blended models mix face-to-face time with online learning time, whereas in fully online course students never meet physically (Van Wart et al., 2019). Recent decade has pushed the new terminology of 'Technology-Enhanced Learning' (TEL) starting in the UK, and supplanting terms like 'learning technology' and 'e-learning'. However, TEL has been criticized as a too wide-encompassing term (Bayne, 2015). For this PhD, therefore, ICT and eLearning were our terminology of choice, and the FC approached as a blended model, as it fits more clearly the ICT use of online delivery to allow students to prepare at home before class.

The advantages of eLearning have been extensively researched in the decades following their introduction. Van Mart et al. (2019) showed that online learning allowed to provide education with reduced expenses for students and faculty, gave flexibility for the students who need asynchronous learning to fit their schedule, and could improve their digital skills. Additionally, the COVID-19 restrictions that pushed institutions to move most of their research online increased further interest in studying eLearning and its impact on students' learning experience. The term ERT (Emergency Remote Teaching) was coined to indicate the specificity of online learning implemented as a "temporary shift of instructional delivery to an alternate delivery mode due to crisis circumstances", using eLearning to provide instructional continuity for a limited crisis time (Hodges et al., 2020). Finally, hybrid learning also became a topic of interest during educational institutions gradual reopening. Hybrid learning aims at adapting to the need for more flexibility by enabling synchronous virtual classrooms to connect both onsite students and remote students during teaching time. Research in hybrid learning appears still in early stages although interest in this form has expanded in the wake of the COVID-19 crisis, allowing flexibility and integration for sick students having to isolate. (Raes et al., 2019)

This PhD aimed at implanting a FC pedagogy, but the model was implanted as ERT and hybrid learning to adjust to the implementation of social distancing rules at

Aalborg University. According to a survey conducted by Marinoni, Van't Land and Jensen (2020), two thirds of HEI respondents implemented distance teaching and learning, experimenting challenges technical infrastructure, skills, and pedagogies, but also opportunities to explore blended and hybrid learning. Increased demands for learning flexibility brings a lot of challenges: recommendations to adjust to the COVID-19 crisis included development of reliable network infrastructure, investment in more affordable technological devices, training initiatives, and diverse modalities in delivering flexible learning experiences (Ferri, Grifoni, and Guzzo, 2020). Therefore, the Flipped learning pedagogical model may yet evolve to accommodate various modes of online delivery, since challenges in implementing it efficiently remain the same: ICT reliability and training, quality of content and stimulating activities, positive and active educator presence, as well as clear organization and guidelines. (Reas et al., 2020)

## 3.4. RESEARCH QUESTIONS

Building upon the research presented in the previous sections, this PhD project addressed the following research questions:

RQ1: Can we build a pedagogical model that expands the FC into a broader educational experience with other active learning activities?

RQ2: How can a FC pedagogical model and educational framework support students and educators through their learning experience?

RQ3: How does online delivery modes impact students' learning experience in the new FC model?

# CHAPTER 4. REFLECTION ON METHODS

During this study, various methodological approaches have been adopted to address the perimeter of our research questions. Figure 1 summarizes the interventions and data collection methods that took place during this PhD project.

## 4.1. INTERVENTIONS

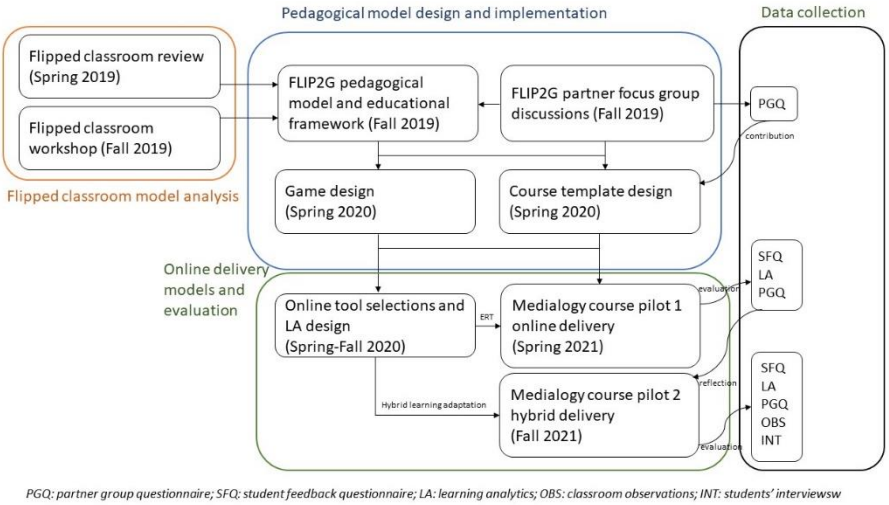


*Figure 1 Interventions and data collection methods*

This PhD research started with a Flipped Classroom model analysis, where extensive reviews of the FC were conducted to determine how the FC pedagogical model had benefited from other forms of active learning. We looked especially in models of FC supported by GBL and LA, as well as potential convergence with Problem-based learning. (Paper I and III) We started then to build an early version of the pedagogical model for the FC supported by PBL, gamification and LA. This version was presented, and its principles discussed during the 2019 workshop conducted at Spel/ICWL conference (Paper IV) and completed by the educators' focus group questionnaire and discussion. The final version of the pedagogical model was used to develop the course design template of the new FC model, to allow its implementation over a wide variety of courses. (Paper V) During this phase of preparation, technological tools were built in collaboration with our education and business partners through a transdisciplinary and transnational Business-University cooperation. Active collaboration in Design and Innovation was conducted to develop

the technological tools used for the project, both a gaming platform supporting gamification in the FC (Paper VI), and a dedicated LA system. Two courses were designed using the dedicated FC pedagogical model in the Medialogy course conducted at AAU and implemented over the course of the year 2021. Due to COVID-19 restrictions, and the allocated time of the PhD study, only two iterations of the course were implanted. Furthermore, due to changes in regulations and the gradual reopening of campus, the first course was delivered fully online as ERT, and the second one through hybrid learning (Paper VIII). The second iteration benefitted from observations from the first iteration to be improved and was also used for in-class observations following a dedicated model (Paper VII). Finally, the information from both iterations of the implemented FC were synthesized into an expanded educational framework to support further uses of the FC pedagogical model. (Paper II)

The scope of this project was to build an original expanded FC model with PBL supported by gamification and LA. Our objective was to assess both students' results and motivation, as well as educators' perception of the model. The theoretical background was centered around the FC and AL methodologies, the technological tools to support implementation of the model, and the contribution of cognitive psychology to analyze motivation and engagement with the model. Figure 2 presents a synthetic representation of the theoretical background for the project.

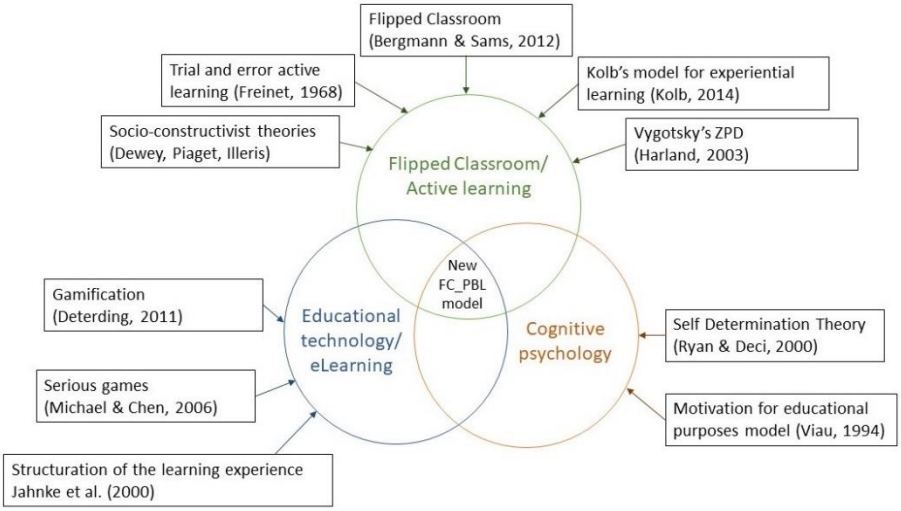


*Figure 2 Synthetic representation of the PhD project theoretical background*

The theoretical framework the research is therefore a socio-constructivist approaches that frame learning through the interactions of the learner with their environment, as well as the social and cultural frame where it appears. This theory is also the backdrop of PBL development, through the pioneering work of Knud Illeris in 1974. Illeris built the key concepts of 'problem formulation' and 'participant-

directed learning', tying them directly to Piaget's theory that learning occurs through the interactions of the individual with his environment, and Dewey's principle that learning processes should be based on the learners' experience (Andersen & Kjeldsen, 2015). Freinet's development of the natural method of education through the trial-and-error experimental procedure play a major part in the constitution of the socio-constructivist framework (Freinet, 1968) Vygotsky's zone of proximal development (ZPD) theory was also an essential theoretical foundation to understand the interactions between learner, project, and environment as part of the learning process (Harland, 2003). Regarding use of technology, our main inspirations lie in Detering (2011) early work in gamification, Michael and Chen (2006) seminal work on serious games and digital game-based learning, and Jahnke et al. (2000) approach of the three components to the learning experience: pedagogical, technological, and social. Finally, self-determination theory (SDT) (Ryan & Deci, 2000) was central in the way we approached the notion of motivation through the prism of cognitive psychology. This theory has been used to frame the FC experience before (e.g., Abeysekera and Dawson (2015)). SDT is concerned with the psychological needs behind motivation and the social conditions that foster these processes, especially intrinsic motivation as an important component of self-directed learning. (Ryan & Deci, 2000) Prior to the SDT, Viau (1994) had established three fundamental aspects in students' motivation: a sense of competence, an understanding the finality of the learning task, and control of the activity. These approaches rooted in cognitive psychology also contributes to the framework of this PhD study.

The project also implied close cooperation both with teachers and educators that would use the proposed model, but technical developers and engineers as well. Each step of the model construction, technical implementation and evaluation was conducted in collaboration with a transnational team to allow the model to be adaptive to other curriculum and contexts.

## 4.2. DATA COLLECTION

During this PhD project, I employed various methods for data collection. My objective was to use mixed methods of data collection and analysis, incorporating both LA data and quantitative data from reflection questionnaires distributed to students and educators alike (Strang, 2017). Furthermore, I also incorporate qualitative data from in-class observations of the gamified activities. (Paper VII), as well as focus groups discussions and interviews with students. Detailed description of the methods can be found in each of the included papers.

Quantitative indicators were central to the implementation of the project since the application of LA meant we had a huge amount of educational data from our students' online interactions. Furthermore, we also used the students' evaluations (both formative and summative) to evaluate their progression over both semesters' iterations. We also used quantitative data from the students' feedback and evaluation

questionnaires, as well as the educators' feedback. This data was important to improve on the model and adjust the second iteration of course. During the second iteration of the pedagogical model, the reopening of campus allowed me to include qualitative methods that could complete the first two sources of data. I conducted in-class observations and students' semi-structured interviews based on models and observation protocols that I designed to frame a more complete picture of the students' learning experience.

Due to the elements presented in this section, we can argue that this PhD project followed the principles of Design research. Design research, also called development research, means to address complex broad problems in education by integrating design principles with robust technological affordances. Design research values intensive collaboration among researchers and practitioners, as well as inquisitive testing and refinement of projects over time. In other words, Design research can be defined as "a commitment to theory construction and explanation while solving real-world problems" (Reeves, Herrington, & Oliver, 2005) which is the ambition which drove this project to design a new educational framework for the FC.

# CHAPTER 5. CONTRIBUTIONS

The main contributions of this PhD project have been published in the attached scientific publications. The project addressed the previously mentioned research questions and focused on three themes: the FC model analysis, the pedagogical model and its implementation, and online delivery modes and their evaluations. In Figure 3, the relation between the attached papers and project research themes is presented.

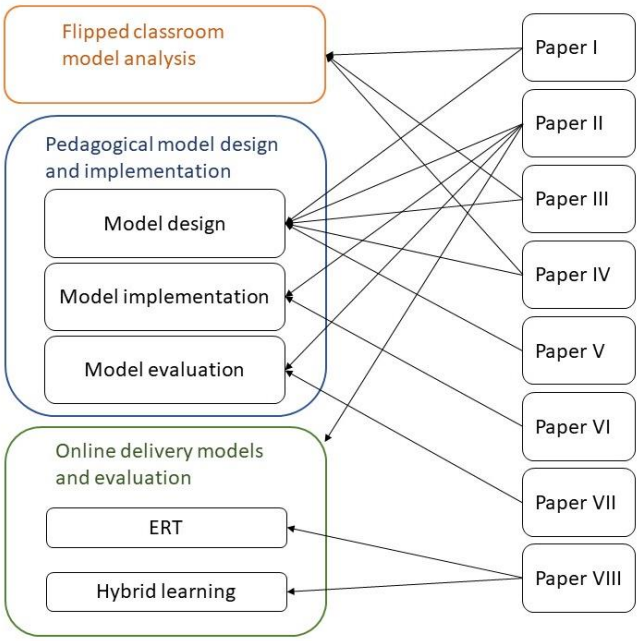


*Figure 3 Relation between the attached papers and project research themes*

## 5.1. FLIPPED CLASSROOM MODEL ANALYSIS AND DEVELOPMENT

In this project, our objective was to expand the FC by incorporating best practices from AL to the pedagogical model and evaluate which brought the best outcomes in terms of performance and engagement. To this end, we investigated previous research and case studies about the FC. We used the scoping review methodology elaborated by Arksey and O'Malley (2005), as this model allows researchers to examine the extent, range, and nature of the research activity, identify gaps in existing literature, and summarize research findings for further use. Two scoping reviews were conducted: integration of GBL in the FC (Paper III), and use of LA to support the FC

(Paper I). The scoping review model was used to argue the potential of expanding the FC model with other active learning methodology as well as supporting the need for an original FC pedagogical model that would enable FC implementation supported by gamification and LA.

Results from the literature review on GBL in the FC allowed us to highlight the potential of incorporating gaming elements of the FC. Many forms of serious games and gamification, both digital and non-digital, have been used in the FC showing a great flexibility and adaptability of the tool. Studies showed that a gamified FC presented better outcomes in terms of performance and engagement than traditional learning or even non-gamified FC. Furthermore, integration of LA in the FC model showed that better performance of students was correlated with higher online engagement in active learning activities, as well as access to feedback on their progress and evaluation. Students also expressed better satisfaction and lower stress with the learning process while invested in active learning supported by LA. However, LA also appeared as a relatively new field in terms of application to the FC, most approaches relying heavily on LMS traces and descriptive analytics.

Investigation results from the literature reviews also revealed that the educational theories supporting active learning methodologies could be used to complete each other, and consistent from one study to another. Deci and Ryan's self-determination theory for example was often cited as a foundation to understand student motivation. Educational models used to support the FC also were exploited such as Kolb's experiential learning cycle or Bloom's taxonomy. Finally, the SRL (Self-Regulated Learning) theory (Pintrich and Garcia, 1994) was also regularly featured. SRL establishes that students can have better learning outcomes, cognition, and behavior with planning, monitoring, and regulating strategies, but also that these strategies are not inherent traits but aptitudes that can be trained. Therefore, we argued that there was potential in integrating the best practices from these various educational approaches as they relied on the same educational principles with a student-centered, autonomous, and holistic learning experience.

An early draft of the pedagogical model for an active learning PBL focused FC was put to discussion during the workshop on Gaming elements and educational data analysis in the learning design of the Flipped Classroom (GALE) that we run at EC-TEL 2019. The first early study into the pedagogical model (Paper IV) focused on the model of the FC that we selected for this project: the four-step wheel model (Gerstein, 2011). We selected this model as a cyclical approach felt a better way to visualize learning as a continuous process whose phases feed off each other. For each phase (1 - concept exploration, 2 - meaning making, 3 - demonstration and application, 4 - experiential engagement), we took feedback from participants to the workshop to start sorting out learning activities and gaming engagement who would be appropriate and efficient for use in the FC. This served as the foundations and basis for development of the actual proposed educational framework.

This PhD project aimed at improving the FC model in an Active learning perspective, with a PBL structure and data-driven approach supported by Game-based learning. Insight from extensive reviews and input from focus groups showed that the Flipped learning approach is becoming more common but needs to be facilitated to support classroom implementation and a solid learning experience. Issues with time, budget, technological and material constraints remain a prominent challenge to address in the FC.

## 5.2. PEDAGOGICAL MODEL DESIGN AND DEVELOPMENT

In this project, the flipped classroom pedagogical model was implemented in the Medialogy course over two semesters in Spring and Fall 2021. A detailed version of the pedagogical model was drafted (Paper V), a dedicated LA algorithm was prepared, and a gaming platform was co-constructed through input from a focus group of educators and business partners (Paper VI). The pedagogical model was improved after the first iteration and expanded into a more in-depth educational framework for application of the data-driven FC with PBL and gamification (Paper II). Data from the implementation and testing of the model included quantitative data from the LA module, educators' impressions, students' evaluation and performance scores, and students feedback questionnaires over the two semesters. Furthermore, I conducted interviews and drafted a dedicated qualitative observation model for gaming activities in the classroom (Paper VII) to complete the quantitative data with qualitative observation and reviews. This mixed method approach generated valuable information from students, educators, and project partners. The project contributions focused on three steps of the FC pedagogical model development: model design, model implementation, and model evaluation.

**Model design**

The objective of the FC pedagogical model was to support learners to analyze, apply and create based on their own construction of knowledge in a student-centered, self-directed learning approach. The pedagogical model design therefore went through three iterations. The first one (Paper IV) focused on the four steps of the FC cycle and how they could be articulated with the main steps of the Aalborg PBL model. The proposed pedagogical model articulated the different phases of the FC as such: 1) Concept exploration/problem formulation; 2) Meaning making/problem analysis; 3) Demonstration and application/problem solving; 4) Experiential engagement/evaluate and reflect. The second phase of the pedagogical model (Paper V) focused on a structure in layers: 1) Learning Activities; 2) Data Generation 3) Learning Analytics. The first layer concerns the course preparation and improvement, the second the running of activities and the data they generate, the third layer the analysis of data, visualization and interventions based on the data. A third and final version of the model was designed as an educational framework (Paper II) after the two cycles of implementation, based on the gathered feedback and data. This

educational framework retained the core elements of the proposed FC pedagogical model but articulated them with the course social interactions and ICT elements to offer a more comprehensive perspective of the learning process.

### Model implementation

The implementation of the pedagogical model was based on dedicated technological support. The project relied on commonly used software through the faculty such as Moodle and MS Teams, but also bespoke platforms for gamification and LA designed for the project. The objective with a dedicated gaming platform was to implement a rewards-based mechanics that could encourage collaborative work and an active feedback loop. The gaming platform was built through a co-design effort, based on the research project partners focus group questionnaire. This preparation work showed that the educators' objectives aligned with the objectives of the FC and active learning, and that challenges were consistent with the research into resistance to the FC (Herreid & Schiller, 2013): the teachers' technological literacy and training and struggle with time constraints, the curriculum constraints in space and time, and limited financial and technical resources. We therefore settled on gamification support with LA that would allow students to access the learning material and play at home, as well as play collaboratively in class, and finally their analytics information to support self-directed learning during the post-class.

### Model evaluation

Evaluation of the pedagogical model showed both strengths, limitations, and potential of the research project. The reflection from educators showed that they managed to follow the educational model and adapt it to their own needs. The educational model enabled to structure the course progression in a dynamic way that implemented PBL learning to support self-directed learning and student autonomy both in collaborative work and individual progression. The perception of the FC by the students over the two courses reflects different experiences, but most students appreciated the possibility to learn and understand the material autonomously, as well as having more flexibility to ask questions in class. "Viewing videos" and "discussing with my classmates" were singled out as the most used activities in the format. Students also showed appreciation for the PBL approach, with a majority of positive feedback answers to the possibility of applying knowledge and solving problems actively. The quantitative data also revealed an increased engagement and performance over the course of the two semesters.

There were some limits to the implementation of the model that were more starkly revealed through the qualitative data. The in-class observation that we conducted in the gaming sessions showed very unequal engagement and dynamics in students. This model, based on the Self-determination theory and gradient of motivation types (Deci & Ryan, 2000), defines students' behavior during playful learning session based on

different forms of motivation. Our gaming sessions presented positive elements in the intrinsic motivation (challenge) category, as well as accomplishment, autonomy, and relatedness. This is consistent for a multiplayer quiz, played in autonomy, focusing on straightforward testing of knowledge with an immediate and quick victory goal, and necessitating a lot of student interaction. The gaming session however also showed higher marks in regulated extrinsic motivation and amotivation, which aligned with observations of a game that needed significant teacher coaching to start, and where some students appeared averse to the gamified approach, and some did not prepare before class. This resistance also showed up in the open answers to the feedback questionnaires and interviews: gamification tends to be generally accepted well or with indifference but presents strong rejection in the students who reject the method.

To conclude we succeeded in building and implementing a pedagogical model applying the PBL approach the FC learning cycle to better frame and design learning activities for FCs and support them with LA and gamification. The integration of gaming elements aimed to support skill development, engagement, and motivation in FC. Finally, the model accommodated the use of LA to provide data-driven feedback to learners in FCs. The model gained some positive feedbacks and limitations were due mostly to technological reliability issues. Its final version was incorporated into a fully holistic educational framework. Due to COVID-19 restrictions, however, we also had to adapt the model to different modes of online delivery and use that were originally scheduled for a regular FC.

## 5.3. ONLINE MODES OF DELIVERY

This project aimed at implementing the pedagogical model as a regular FC, with at-home online learning and in-class hands-on activities. However, when the COVID-19 pandemic imposed social distancing restrictions, the project was adapted to different eLearning circumstances. This allowed us to expand the project's scope from the FC to different modes of online delivery. This also gave us a unique opportunity to observe students' attitudes during the main phases of lockdown and gradual reopening of campus. (Paper VIII)

The first semester of implementation was conducted in Spring 2021, when the campus was on lockdown, and was run as a full ERT course. Students had to prepare before the online classes as a regular class, and the in-class activities were conducted as an online synchronous lecture and group work. During Fall 2021, the campus was gradually reopened, and teaching became hybrid: some classes were run online, and some were run physically in class. Additionally, the in-class sessions were broadcasted so that students who had to or preferred to stay home could follow the lectures online.

The fact that the model could be implemented with different online structures than anticipated is a testament to the flexibility of the FC, and the Flipped learning approach. Interviews with students showed that they expressed satisfaction to be back physically in class. However, they also showed that students appreciated the hybrid format, the possibility to access to the lectures online during or after the class, and to follow it online when they cannot attend in person.

Additionally, the analysis from the LA and online interactions showed that students showed several different behaviours from students' groups. A minority of high performing students worked consistently and prepare in time. One group of students attended most physical classes and also performed a little better. Another group mixed online and physical classes in almost equal proportion, and a final group took all lectures online, sometimes completing the semester very last minute. The results underlined that regular preparation and physical interactions correlated positively with both summative and formative evaluation. These results underline the importance to support these elements in future iterations of the model, and that sustaining regular engagement and motivation shall remain a key issue for Flipped learning moving forward.

# CHAPTER 6. CONCLUSION

## 6.1. DISCUSSION ON CONTRIBUTION

The project presented insights into the FC methodology and analyzed the challenges and difficulties and the model, while providing leads for its improvement. Early investigations into the scientific literature showed that there is potential in structuring the FC with PBL elements and supporting it with GBL and LA. However, this investigation also showed that there are many challenges remaining to further expand the FC model: need for digital literacy and competence, reliable and stable technology, ensuring student motivation and regular engagement before class. This PhD study proposed models to improve the FC by structuring it as a student-centered, PBL based experience. This study also highlighted models to use Learning Design to support the FC implementation.

The project contributed an original data-driven problem-based FC pedagogical model supported by gamification. The objective was to improve on the FC model by incorporating best practices from established and tested AL methods. The pedagogical model was implemented over two semesters, was improved through two iterations, and the final model was incorporated in an original educational framework. During the evaluation, a pre- and post- feedback questionnaire was used, as well as the quantitative data from the LA, online interactions, and summative and formative evaluation. Semi-structured interview forms and a dedicated in-class observation model for playful learning were also designed and used. Results from testing the model showed that both students and educators were receptive to the method. They valued mostly the flexibility of the model and capacity to learn at their own rhythm, which became critical over the course of semesters perturbed by the COVID-19 social distancing mandates. Those results also show that stability and accessibility of technology remain crucial in adoption by learners and educators alike.

As far as online interactions and modes of online delivery are concerned, the pedagogical model showed its flexibility when it had to be adapted for fully ERT first, and a hybrid classroom next. As the need for more flexibility is to be expected in the future, pedagogical models offering a clear educational framework for implementation and adaptive data-driven solutions will turn valuable. Comparative results from both semesters showed that students benefitted from face-to-face time but appreciated the flexibility of being able to access the lecture and material at their own pace, as well as connecting synchronously to the lecture if they had to remain distant. This shows that the borders of the FC are becoming more and more porous: in time, we might not work so much with Flipped “classroom” and more with the toolbox of Flipped “learning” to be adaptive to each specific educational context.

Thus, this project contributed to theoretical discussion on the flipped classroom model, as well as ICT for education and eLearning. The project also provided concrete design and tools for implementation of the PBL flipped classroom supported by LA and gamification, as well as improved its pedagogical model over both iterations. The findings of this project offer sone insights into the future development of the FC, as well as implications for running eLearning and hybrid classes in more uncertain contexts. The implication for future FC and ICT-based learning development may be the foundation for expanding Flipped learning as a more holistic learning experience.

## 6.2. DIRECTIONS FOR FUTURE WORK

This PhD project has investigated the flipped classroom model to see how it could be expanded and improved. It proposed a pedagogical model for a cyclical data-driven PBL FC supported by gamification to attain this objective. It studied student motivation and engagement during the implementation of the new model and experimented with different contexts for online learning and ICT use. These contributions offer several directions that future research can address.

Regarding the flipped classroom approach the proposed model and related educational framework may be employed to design further flipped learning courses and expanded again with other active learning activities. Furthermore, the model was designed to be adaptable to various subjects and contexts and could be beneficial to trans-disciplinary approaches of PBL.

In the field of eLearning, Technology-Enhanced Learning, and hybrid learning, this project offers an early insight into flexible modes of course delivery and can be used further to support the implementation of hybrid solutions.

Finally, this project highlighted the technological struggles that are still a major challenge in learning technologies and the need for consistent, reliable software to that end. Moodle represents a prime example of a technology, the LMS, that used to be more diverse but mostly whittled down to the most user-friendly, widely used software. This project presents insights that may support a similar evolution for gamification or LA applied to Flipped and playful learning.

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