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Online environments for supporting learning analytics in the flipped classroom: a scoping review

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Abstract: The Flipped Classroom (FC) is an instruction method, where "events that have traditionally taken place inside the classroom now take place outside and vice versa", which has known a significant surge of popularity in the past decade. In FCs, different types of activities may take place depending on the session type (pre-class, in-class, or after-class), the learning objectives to fulfil, the type and size of the class, the available infrastructure, the time available etc. In order to support the activities taking place in FCs, instructors can use various technological tools and online environment, especially to support the preparation of students before class. A marked recent trend in the FC is the increased use of Learning Analytics (LA) to support the development of the FC and students' reflexive learning. However, there has been no systematic investigation into combining LA and the FC, and it appeared that there was a lack of research on the issue. The aim of this paper is to investigate the literature on applications of LA in FCs, and to determine the best practices and needs for technological development supporting LA in the FC. In order to perform this study, we did a scoping review of literature in the subject to determine research trends in the use of LA in the FC. We conclude that there is great potential to use LA in the FC, and try to project where further research is heading.

Keywords: active learning, flipped classroom, learning analytics, virtual learning environment, MOOCs

1. Introduction

The FC is possibly one of the most emblematic endeavours to overhaul educational practices in recent years. Faced with the need to engage students, and with disaffection from the traditional lecture-based model, educational institutions turned towards active learning to shift "…the focus of learning from passively receiving content information to diligently participating in learning activities" (Frey, 2018). In that regard, the FC, where "…events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa" (Lage et al., 2000) is a concrete application of the principles of active learning. After a first decade of developments and tests of the model, the FC is undergoing further developments, amongst which the increased use of LA (Fernández et al., 2018).

1.1 The Flipped Classroom (FC)

Interest for the FC however rose sharply in the early 2010s, following its popularization in secondary education in the Unites States (Bergmann & Sams, 2009). It is now frequent in higher education, as a means to engage an increasingly diverse and flexible population of students (Reidsema et al., 2017). Abeysekera and Dawson (2015) provide a "lowest common denominator" definition; defining the FC 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."

The FC methodology has been frequently reviewed and studied, and interest in the methodology has remained constant in the past decade (Bishop & Verleger, 2013; O'Flaherty & Phillips, 2015; Zainuddin & Halili, 2016). The FC has been recognized as an effective learning approach in various courses: it gives teachers more time for personalized interactions with students, improves students' creative thinking and communication skills, and encourages students' responsibility in their learning (Lin & Hwang, 2018).

1.2 Learning analytics

Based on the most commonly cited definition, "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." (Siemens & Long, 2011). Figure 1 presents the different steps in the LA process.

Figure 1: The different steps in the LA process

LA aim at providing ways to gather and make sense of educational data, which is is generated while educators and learners interact with digital technologies, in order to improve the learning experience for learners and teachers, and better adapt courses' design. Although LA is a relatively young field, it might prove crucial in further developments of the FC since it can inform teachers about the learning process of the students, and teachers can in turn use this information to make informed pedagogical decisions (Van Leeuwen, 2018). The method also encourages adaptive learning and self-regulated learning: learners can improve their meta-cognitive abilities with information to reflect on their own learning, and teachers can create a feedback loop between online and classroom phases to assess the progress and needs of students (Klemke et al., 2018).

1.3 Combining the flipped classroom and learning analytics

Although both the FC and LA have both been active fields of studies, research in combining them is still rare. According to Fernández et al. (2018), early research focused on the results obtained in the FC, or used specific indicators to obtain useful information for the FC. However, that research did not indicate precisely what the best tools were, or what specific learning activities they could support.

This article means therefore to complete the existing literature by examining the potential in combining the FC and LA through a scoping review of the existing literature. We believe that examining previous use of LA in the FC will allow us to determine how LA have been used successfully, and where use of LA is still lacking. There are several advantages to using a scoping review. According to Arksey and O'Malley (2005), it allows researchers to examine the extent, range and nature of the research activity, to determine the value for undertaking a full systematic review, to summarize and disseminate research findings, and to identify gaps in existing literature. We will therefore research the implementation of LA in the FC, and determine the best practices, the limitations, and how it can be improved.

2. Methodology

For this paper, we have used Arksey and O'Malley's methodology (2005), as expanded by Levac et al. (2010). The scoping review method uses the stages presented in the following sections.

2.1 Stage 1: identifying the research question

The focus of this research is to explore the key factors to use LA in the FC. We also want to examine how LA can improve the FC model. To ensure that a substantial range of literature was examined, we followed the initial research questions to guide the search:

1. Which type of data and learning theories can be used to implement LA in the FC?
2. What were the educational outcomes of using LA in the FC?
3. What were the main limitations in the use of LA in the FC?

2.2 Stage 2: identifying relevant studies

Arksey and O'Malley suggest that a wide definition for search terms should be used. Therefore, we opted for a large selection of related terms, which covered various forms of LA. The following research string was thus devised:
("flipped classroom") AND (("learning analytics") OR ("engagement data") OR ("educational data") OR ("activity data") OR ("data mining")). The selection was then restricted to research that specifically used LA in the FC.

The selected databases for this study were Scopus, Proquest, Web of Science and Google Scholar. Only peer-reviewed articles and papers, accessible in English, and in the period 2009-2019 (which coincides with the exponential development of the FC and LA) were researched.

2.3 Stage 3: Study selection

Using the key search descriptors, we identified 90 articles. Duplicates, papers covering theoretical models, reviews or workshop descriptions lacking any results were excluded. We finally ended with a final selection of 39 articles.

2.4 Stage 4: charting the data

The data extracted from the selection of articles was mapped using the following criteria: Study ID, Database, Paper title, Journal/proceeding, Author, Year, Country of study, LA algorithms, Data extracted, Feedback to students, Position in the FC, Level of class, Subject, Size of class, Control group (if applies), Outcomes, Evaluated variables, Methodology, Evaluation of performance (grade, knowledge test, learning outcomes), Evaluation of students perception (self-reported opinion, interviews, interest, attitudes), Student experience (motivation, stress level, engagement, participation, cognitive load), Theoretical framework, Limitations.

2.5 Stage 5: collating, summarizing and reporting the results

The final stage of the scoping review summarizes and reports findings.

3. Findings

The 39 selected articles represented 15 countries of study. Most studies were conducted in the USA (8 articles), then in China (including Hong Kong) (7 articles), then Australia (5 articles), and many other countries such as the UK, Spain, and Brazil. The oldest article is from 2014, illustrating the rather recent interest of development of LA in the FC. The majority of articles, 15 out of 39, were published in 2018, and with 5 articles for the first half of the year 2019, the trend remains solid. All but three studies were conducted in University classes, with a significant majority of STEM related subjects: Computer science (9 articles), Engineering (8 articles), Math (4 articles) and Science (3 articles). We may explain this finding by the fact that such subjects allowed researchers easier access to data mining algorithms, technical support, and statistical proficiency.

3.1 Which type of data and learning theories can be used to implement LA in the FC?

Data mining and exploitation of Learning Management System (LMS) traces, especially in Moodle, is the main source of data in the articles we reviewed, appearing in 29 articles (e.g. Gelan et al., 2018; Yamada & Hirakawa, 2015). LMS traces can be varied, but usually cover such basics as time spent on lesson (Matcha et al., 2019), completion of online activities (e.g. Poon et al., 2017; Ayres et al., 2018), and regularity and frequency of engagement with the platform (e.g. Jovanovic et al., 2019).

A significant number of studies focused on the pre-class preparation through engagement with the video lectures, with 9 articles (e.g. Xiao et al., 2015). In these articles, the focus was on data as interactive notetaking (Hecking et al., 2017; Pardo et al., 2015), the results from embedded multiple choices questionnaires in the video (e.g. Giannakos et al., 2015), multiple views and unique viewers per video (Gilliland, 2017), or the assessment of the video quality by the learners (Giannakos & Chrisochoides, 2014).

Three studies focused on social interactions as a means to engage learners in the learning process, using data as their comments on the Facebook page used to present the pre-class material (Lin & Hwang, 2018), the interactions with peers or teachers in the MOOC platform (Ji & Han, 2019), or the volume of submissions on the system (Isomöttönen & Tirronen, 2017).

Some articles focused also on student metrics, such as the completion rate and success rate in the course (Kaw, et al. 2019; Yang et al., 2016), students self-reported satisfaction in the experience (Lei et al., 2017; Van Leeuwen, 2018), students self-assessment regarding their performance (Corrias & Hong, 2015) or self-regulation in learning (Hwang & Chen, 2019).

While we underline for this review the focus for each study, most studies used data from several sources, and almost half completed their exploitation of LA with qualitative data (18 articles).

As for the theoretical background, few articles connected their research to a clearly identified theoretical background. Most articles introduced fundamental notions such as the flipped classroom, MOOCs (Ng & Xie, 2017), video-based learning (Garrick, 2018), two articles referenced the principle of active learning (Kaw et al., 2019; Hui et al., 2018), and another two referenced Bloom's taxonomy to analyze the efficiency of the FC (Hwang & Chen, 2019; Giannakos et al., 2015). However, less than half of the articles (14 over 39) made a specific use of educational or learning theories. The self-determination theory as developed by Deci & Ryan (1985) thus appeared in two articles (Sergis et al., 2018); Isomöttönen & Tirronen, 2017). The main theoretical frame, however, was undoubtedly the notion of Self-Regulated Learning (SRL) and learning strategies, presented in 11 articles (e.g. AlJarrah et al., 2018; Silva et al., 2018; Saint et al., 2018; Fincham et al., 2018; Jovanović et al., 2017; Sun et al., 2016; Pardo et al., 2015).

The SRL theory (Pintrich & Garcia, 1994) establishes that students can have better learning outcomes, cognition, and behaviour with planning, monitoring, and regulating strategies, but also that these strategies are not inherent traits but aptitudes that can be learned and brought under control. Therefore, many studies used this theory as a means to encourage the use of LA to support students' self-regulation in learning and metacognitive strategies.

The choices made in terms of LA algorithms and exploitation of data supports this notion. Indeed, we identified in these studies three main interests in data exploitation: clustering, predictive analysis using especially the linear regression model and, less frequently, sequential analysis. We classified these data algorithms according to the following uses:

- *Sequential analysis* was used to determine the general trends in online engagement, especially the distribution of online engagement and activities over the duration of the whole course
- *Clustering* was used to define students' profiles depending on their online engagement habits and frequency
- *Predictive statistics* were used to correlate students' profiles with the students' results or pass grade and try to predict students' success based on their learning profile and engagement in the FC and online activity.

3.2 What were the educational outcomes of using LA in the FC?

Based on the aforementioned elements, we can now question what the learning outcomes observed by integrating LA in the FC were. Most studies, 16 out of 39, focused on the correlation between students' learning performances and online activity, and found positive results correlating the highest grades and pass rates with the most active learning strategies (e.g. Hsiao et al., 2018; Martínez-Muñoz & Pulido, 2015; Smallhorn, 2017). Two studies among these especially highlighted the positive impact of students engaging with online feedback on their learning process on higher levels of SRL and better learning outcomes (Matcha et al., 2019; Silva et al., 2018). Studies who also investigated the students' perception of the process found high level of students' satisfaction in the learning experience (Lei et al., 2017; Corrias & Hong, 2015; Smallhorn, 2017).

The second most represented outcome of these studies, with 13 articles, was the use of LA as a means to improve the learning experience and the FC process. Such studies offered LA to help teachers improve the course (e.g. Van Leeuwen, 2018), to enable adaptive learning by selecting the best material and exercises according to the student's profile (e.g. Xiao et al., 2015), or to select the best learning materials and videos (e.g. Lau et al., 2018; Kravchenko & Cass, 2017). Within this group, some studies focused on the temporality of students' engagement with the learning material to issue recommendations for adaptive learning and improvement of the learning material (e.g. Garrick, 2018).

Therefore, the majority of studies presented positive results and made a compelling argument to the idea that LA can be used effectively to predict students' success based on their online engagement and learning strategies in the FC. Furthermore, these studies showed that using LA in the FC could reinforce the method by providing an adaptive learning framework to students, and encourage SRL.

3.3 What were the main limitations in the use of LA in the FC?

Although the impact of implementing the FC and the use of LA seemed overwhelmingly positive, this review allowed us to observe several limitations, especially the issues connected to students' engagement with the learning material, limited use of feedback and LA on learning strategies, and students' difficulties to adopt the methodology. Twelve articles out of 39 presented similar issues, which we can decompose into the following specific problematics:

- *Quality of engagement:* several studies (e.g. Marasco et al., 2018) underlined that the measures from LA were mostly click-based, and did not evaluate the quality of students' engagement with the learning material.
- *A utilitarian engagement:* two studies (Ayres et al., 2018; Smallhorn, 2017) underline the fact that many students only performed the learning activities before the exam, or if grades were attached to them.
- *Specific difficulties:* some studies underlined the difficulties of students to self-regulate their learning process (Isomöttönen & Tirronen, 2017), or the reluctance of already high-performing students to adopt new learning methodologies (Pardo et al., 2015).

Some studies also underlined negative or non-significant results. For example, there could be no statistical difference between passing and failing students (Gelan et al., 2018), no correlation between success rate and time spent online (Yang, et al., 2016), a disappointing pass rate due to lack of quality engagement with the learning materials (Lei et al., 2017), or no effect for the highest performing students (Jovanovic et al., 2017).

Finally, we observed the fact that only eight articles allowed students direct access to feedback information, or their own learning analytics (e.g. Jovanovic et al., 2019). This limited use of feedback to students shows that there is room to improve the use of LA and its potential to develop fully adaptive learning.

4. DISCUSSION

4.1 Data and learning theories

This scoping review shows that there is great potential in using LA in the FC, especially as a means to reinforce the efficiency of the methodology. Improvements in technology allow instant access to a wide range of educational data. However, we observed that, because of its reliance on online educational data, most studies focused on the pre-class preparation, and approached the post-class process only through students' summative assessments and results. There is, therefore, a clear lack of research investigating the in-class process and activities.

Furthermore, to inform and improve educational practice, key researchers have underlined the need for LA to be rooted in research on learning and teaching (Gelan et al., 2018), and our research showed that studies in applying LA to the FC focused so far mostly on the technical aspects and didn't articulate their results with in-depth learning theories.

The most promising angle we observed is the use of SRL theory to analyse and understand patterns in students' behaviour and learning strategies. There is, therefore, an under-investigated potential in putting more emphasis on SRL, and giving better feedback and access to LA to students to develop fully adaptive learning.

4.2 Educational outcomes and limitations

The majority of studies presented positive learning outcomes and the capacity to predict students' success and pass rates based on their online engagement with the learning materials and activities with their peers and teachers. However, our analysis showed that there are still fields that remain underexploited regarding LA in the FC.

Few studies tried to investigate the long-term effects of the FC, and used only students' results on a given course. Indeed, some groups showed no significant improvement in short-term assessment in the FC, but improved results in long-term assessment (Hsiao et al., 2018). Similarly, few studies investigated the effect on different populations of students. Some only used the video metrics without evaluating individual users'

engagement (e.g. Kravchenkoc & Cass, 2017), and only two studies presented a different population. Kaw et al. (2019) investigated students "other than white male" and Ng & Xie (2017) showed that the FC was slightly more efficient with female students.

Finally, our research shows that there are still issues that need to be resolved to implement efficiently LA in the FC. For example, click-based data can only measure superficial online engagement and should be completed by either qualitative data, focus groups, or students' social interactions. Marasco et al. (2018) even suggested that the whole system of evaluation should evolve to fit the new paradigm.

5. Conclusion

Faced with the necessity to promote and develop active learning, educational institutions have turned massively towards the FC to encourage self-regulated learning in students. As the efficiency of the FC became well established, the potential of improving the FC by using LA seems a logical step forward. Our literature revealed that there is potential in using LA in the FC, especially as a means to predict students' learning outcome and to support adaptive learning and improvement on the curriculum. However, further research and development is necessary to encourage self-directed learning in students and to develop the whole of the FC for a more diverse population of students.

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