1. Introduction

Blended learning environments supported by the Flipped Classroom Model (FCM) have been the subject of increased attention in both research and practice (O’Flaherty & Phillips, 2015; Lo & Hew, 2017). The FCM has been studied primarily as a means to enhance the teaching and learning process and optimize the exploitation of teaching time in face-to-face school sessions, by replacing teachers’ lecture with more (collaborative) hands-on activities and individual scaffolding (Bergmann & Sams, 2012).

This standpoint of the FCM, and its potential benefits for the teaching and learning process, have been investigated by a significant body of research, across different subject domains and educational levels (Bishop & Verleger, 2013; Giannakos, Krogstie, & Chrisochoides, 2014; Lo & Hew, 2017). More specifically, the clear majority of this pool of evidence argues that FCM can indeed deliver diverse benefits, spanning from helping teachers improve the teaching and learning conditions for their students (e.g., Aidinopoulou & Sampson, 2017; Kostaris, Sergis, Sampson, Giannakos, & Pelliccione, 2017), and also enhancing students’ cognitive learning outcomes (e.g., Kong, 2014), skill development (e.g., Tanner & Scott, 2015) as well as overall motivation (Baepler, Walker, & Driessen, 2014; Sahin, Cavlazoglu, & Zeytuncu, 2015).

Despite this evidence base, however, a shortcoming of existing works is that they have focused on investigating the impact of FCM on particular aspects of students’ learning, primarily cognitive learning outcomes and overall motivation (Lo & Hew, 2017). The standpoint of this paper is that there is another dimension to be addressed issue and investigate, in an exploratory manner, the impact of FCM-enhanced blended learning environments not only on students’ cognitive learning outcomes, but more importantly on their internal dispositions (level of satisfaction) and ‘needs’ for competence, autonomy and relatedness. The work builds on educational data and evidence from three different implementations of FCM in action research studies across diverse K-12 subject domains, and reports on a consistent pattern of positive findings regarding the capacity of FCM-enhanced blended learning environments to improve the aforementioned aspects of students’ learning outcomes and experiences, with a particular added value for low-performing students.

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also fulfill their motivational ‘needs’ for engaging in the learning process, which can ultimately lead to the recurrently observed improvements in performance and overall motivation (Abeyesekera & Dawson, 2015). According to the prominent Self-Determination Theory (Ryan & Deci, 2000), these ‘needs’ relate to the need for autonomy, relatedness and competence, and have been repeatedly utilized as the means to study the underlying factors of students’ performance and activity in the learning process (Guay, Ratelle, & Chanal, 2008).

This additional layer of insights on the impact of FCM is worthy to be investigated since it has the potential to facilitate practitioners and researchers identify not only whether FCM can be used to attain better experiences and outcomes in ‘standalone’ interventions (e.g., a single course) but also whether and how it may drive more systematic improvements on students’ dispositions and fulfillment of internal ‘needs’ towards the learning process, leading to more replicable and sustained improvements.

This work aims to address this issue and investigate the impact of FCM-enhanced blended learning environments on students’ cognitive learning outcomes, as well as students’ satisfaction and self-determination for their learning. The contribution of this paper is to present initial findings derived from three different implementations of FCM in action research studies across diverse subject domains (i.e., Math, ICT and Humanities). Initial insights from some of the studies used in this paper have been reported in prior works (Katsa, Sergis, Sampson, 2016; Kostaris et al., 2017), primarily relating to the impact of FCM on students’ cognitive learning outcomes. This paper extends the findings of these prior works and enriches the existing understanding of the potential of FCM from a different and novel perspective. The remainder of the paper is structured as follows. The Background section outlines the key concepts supporting this work, namely (a) the FCM and an outline of existing evidence on its impact on students’ learning and (b) Self-Determination Theory and how it has been used in this work to define a framework for measuring the impact of FCM on students. The Research Methodology section outlines the methodology used in each study, whereas the Results section presents the obtained findings against the defined research questions. Finally, the Conclusions and Future Work section summarizes the main take-aways from the paper and discusses potential future research paths.

2. Background

2.1. Flipped Classroom Model

The FCM is an emerging learning model which aims to increase students’ active learning, collaboration and scaffolding during the learning process, through a better allocation of teaching time (Bergmann & Sams, 2012). More specifically, the FCM posits that teaching time within the face-to-face school sessions should not be spent on teachers’ lecturing, but instead should be invested to provide students with unique learning experiences within collaborative activities with their classmates as well as receiving scaffolding by their teacher (DeLozier & Rhodes, 2016). To accomplish this, digital technologies in the form of learning environments (e.g., Learning Management Systems) as well as educational material (e.g., educational videos and online quizzes) can be used to engage students in “home-based” study and self-assessment, before the school-based sessions (Chen, Wang, Kinshuk, & Chen, 2014). In this way, teachers’ lecture can be replaced by these materials and, the corresponding classroom time can be allocated on offering engaging learning activities.

The FCM has received a significant level of attention from both practitioners and researchers, spanning a range of subject domains including Mathematics (e.g., Katsa et al., 2016; Muir & Geiger, 2016), ICT (e.g., Giannakos et al., 2014; Reza & Baig, 2015), Social Studies (e.g., Aidinopoulou & Sampson, 2017) and Humanities (e.g., Grossman, Grossman, Azevedo, Figueiro-Filho, & Mckinley, 2015). The clear majority of these works has investigated the impact of FCM on a specific set of dimensions, primarily students’ cognitive learning outcomes and overall motivation (Lo & Hew, 2017). To give a few examples, Kostaris et al. (2017) offered pioneering insights on the impact of FCM in junior high school ICT studies, and positively evaluated the impact of FCM on increasing students’ cognitive learning outcomes and overall motivation compared to a control group participating in a ‘non-flipped’ course. Moreover, the study reported interesting findings that low-performing students reaped the highest levels of improvement in their performance. In the context of Math, Reyes-Lozano, Meda-Campana, and Gamboa (2014) reported that the FCM improved students’ cognitive learning outcomes in a K-12 Math course, evidence which are corroborated by Bhagat, Chang, and Chang (2016), who also reported positive influence on students’ motivation as well. Additionally, Katsa et. al. (2016) reported that students exposed to a FCM-enhanced high school Math course improved both their cognitive learning outcomes as well as their level of motivation. A deeper layer of analysis of students’ performance improvement also indicated that low-performing students presented the highest level of increase. Finally, in the context of Humanities, Hung (2015) reported that the FCM significantly benefited students’ cognitive learning outcomes and motivation, measured through their effort as well as attitudes invested in the learning process. Also, Huang and Hong (2016) reported that students’ English reading comprehension improved significantly during the FCM-enhanced learning intervention.

Overall, beyond the previously discussed works, an additional large body of literature exists on studying how the use of FCM impacted students’ cognitive learning outcomes and overall motivation. However, despite this pool of insights, the existing body of knowledge is surprisingly scarce when it comes to studying how FCM can affect more internal dimensions of students’ learning experiences, including their level satisfaction throughout the learning process as well as their internal needs for effectively engaging in the learning process, namely autonomy, relatedness and competence (Abeyesekera & Dawson, 2015; Ryan & Deci, 2000). It is argued that obtaining this layer of insights could provide new evidence regarding the underlying reasons for the reported benefits of the existing studies on FCM, therefore it is considered worthy to be investigated. In this context, this paper will adopt the principles of Self-Determination Theory as the primary theoretical framework, in order to define the internal needs of students during the learning process. The following section presents the basic constructs of Self-Determination Theory adopted in this work.

2.2. Self-determination theory

Self-determination theory is a theory that builds on the concept of motivation and aims to describe the inner ‘needs’ of individuals (in this case, students) that may affect their experiences and performance in a given situation (in this case, the learning process) (Ryan & Deci, 2000).

At its core, self-determination theory defines three basic dimensions which relate to the aforementioned student needs: Competence, Autonomy and Relatedness. More specifically (Ryan & Deci, 2000):

- Competence is related to the need of students to feel capable to successfully engage in the learning process.
- Autonomy is related to the need to be engaged with tasks in an autonomous manner within a context that is relevant to them.
- Relatedness is related to the need to be engaged in tasks that allow collaboration and communication with other students.

Capitalizing on this modelling, self-determination theory has been extensively utilized and validated in the educational field in both empirical and conceptual studies (over 200), as a means to study students’ motivational needs in a highly granulated manner (Guay et al., 2008). However, despite its wide adoption, it has yet to be explicitly utilized in studies focusing on the FCM model, even though such a potential has been repeatedly stressed (e.g., Abeysekera & Dawson, 2015; McLaughlin et al., 2014; Seery, 2015).

Therefore, considering the extensive adoption of self-determination theory in the educational research filed as well as the direct relevance of the theory to the problems outlined in this work, it has been selected as the background framework, in order to study whether and how FCM-enhanced blended environments can affect students’ motivational needs.

Capitalizing on this theory, the contribution of this paper is to provide exploratory insights, derived from three separate implementations of FCM across three different K-12 subject domains (i.e., Math, ICT and Humanities), regarding whether (and how) FCM-supported blended learning environments can affect students’ cognitive learning outcomes, and also drive more internal impact on students’ satisfaction as well as their self-determination for their learning. The following section presents the research methodology adopted in this work.

3. Research methodology

3.1. Research questions

Based on the discussion of the previous section, a set of three research questions were defined so as to further enrich and complement the existing understanding on the impact of FCM-enhanced blended learning environments:

RQ1. Does the exploitation of FCM contribute to enhancing students’ learning outcomes? If yes, what is the impact of FCM on different performance-based student clusters (based on their prior level of cognitive outcomes)?

RQ2. Does the exploitation of FCM contribute to enhancing students’ learning satisfaction during the learning process? If yes, what is the impact of FCM on different performance-based student clusters (based on their prior level of cognitive outcomes)?

RQ3. Does the exploitation of FCM contribute to enhancing students’ self-determination during learning, namely sense of competence, autonomy and relatedness? If yes, what is the impact of FCM on different performance-based student clusters (based on their prior level of cognitive outcomes)?

3.2. Context and sample of studies

As aforementioned, this paper draws from the findings of three distinct action research studies which investigated the potential of FCM-enhanced blended learning environments on students’ learning experiences and outcomes in real-life K-12 school settings.

More specifically, these studies were related to (a) an ICT course in junior High school (equivalent to the 8th grade; students approximately 14 years old) (Study #3). Fig. 1 presents the outline of the sample used in each of the three studies. As depicted, each study adopted a quasi-experimental control-experimental group protocol and the total sample size was 46 for Study #1, 40 for Study #2 and 42 for Study #3. In each study, the experimental group was engaged in the FCM-enhanced instance of the course, whereas the control group was engaged in a face-to-face only instance of the same course. More details on the educational design and delivery considerations for each courses’ instance are provided in the next section. Finally, full consent attainment and data anonymization processes were implemented prior to all studies (see Kostaris et al., 2017 for details).

3.3. Procedure

All three studies utilized in this work were conducted as part of action research protocols implemented by senior teacher practitioners. More specifically, action research is a reflective process for investigating and improving practitioners’ practice through the collection, analysis and interpretation of educational data collected during the research (Cohen et al., 2007). The three action research studies were designed based on Lewin’s model (1948), which argues that such studies should comprise four step-wise phases, namely the Plan phase, the Act phase, the Observe phase and the Reflect phase.

Consistently across the three studies, the Plan phase included the definition of the action research questions, methodology and evaluation protocol. Additionally, it included the design and development of the teaching and learning processes that will host the action research, namely the FCM and ‘control’ instances of the courses. The Act phase referred to the delivery of both course instances defined in the previous phase to the students of the corresponding group. The Observe phase referred to the implementation of the action research within the teaching and learning process and the collection of the educational data needed to address the research questions. Lastly, the Reflect phase comprised the analysis of the collected data and the generation of insights to answer the research questions.

The three action research studies also shared a common pattern in the way they were designed and implemented, which was formulated jointly by all practitioners involved in these studies. More specifically, during the Plan phase, which was completed over a three-month period, the action research methodology was defined and the educational design of each study’s course was formulated. Finally, the online environments for hosting the learning activities beyond the physical classroom for the experimental groups (based on Moodle Learning Management System [https://moodle.org]) were also developed.

Regarding the educational design of the courses used in the
experimental and control groups in each study, they were designed with the highest level of similarity, to minimize result bias. More specifically, each set of course instances shared the same educational objectives as well as frequency and duration of face-to-face sessions. Furthermore, they utilized the same teaching approaches (mainly problem-based and project-based approaches) and techniques (mainly the Jigsaw technique, Think-Pair-Share technique and the Brainstorming technique). Finally, each set of course instances shared identical assessment methods, which included both written tests (contributing to students’ grades) as well as collaborative projects between students.

In terms of how each the two instances of the courses were delivered, the main difference referred to the way that the learning activities were distributed between the face-to-face classroom sessions and the ‘home-based’ sessions. In particular, the delivery for the control course instances was initiated during the face-to-face classroom session, in which the practitioner presented the new learning material. After this activity was finalized, the remaining face-to-face time was invested in students’ engagement in (collaborative) hands-on activities relevant to the scope of each session. At the end of each face-to-face session, the practitioner assigned homework to students, to be completed at home. The delivery for the course instances for the experimental groups was initiated from a home-based, pre-session hosted in Moodle. During this pre-session, students were prompted to study the basic concepts of the upcoming face-to-face classroom session using learning material provided by the practitioner (mostly educational videos) and also self-assess their understanding of this material through online quizzes. By allowing this, the practitioners were able to free-up the lecturing time in the classroom session and invest it on (collaborative) hands-on activities for their students, as well as the provision of scaffolding and feedback. It should be mentioned that the time invested by students engaging in learning and assessment activities in the experimental and control groups were similar, both in the classroom-based session as well as in the home-based sessions.

The Act and Observe phases followed the completion of the Plan phase and were aligned to the delivery of both course instances in each study, namely 8 school weeks. Finally, the Reflect phase lasted two months for each study and aimed to analyze and interpret the educational data which were captured using the data collection methods presented in the next section. Based on these analyses, the defined Research Questions were addressed. The data analysis methods utilized in the Reflect phase are presented in the following section.

Finally, it should be mentioned that all studies adhered to a specific protocol for study trustworthiness, building on the work of Shenton (2004), and addressing criteria of credibility (internal validity), confirmability (objectivity), transferability (external validity) and dependability (reliability). Specific details can be found in Kostaris et al. (2017).

3.4. Data collection

All three action research studies employed data triangulation, using different data sources, in order to increase robustness of findings (Phillips & Carr, 2010). Given the exploratory nature of the defined RQs of this work (especially RQ3), a core standpoint influencing the data collection (and analysis) protocols was to capture and exploit data from diverse sources. This was done so as to have a rich dataset to investigate the defined RQs and enable better interpretation of the results. Therefore, the data collection methods included both student-reported data (based on questionnaire items) as well as data collected from the teachers, related to both teachers' assessments (i.e., assessment scores and engagement rubrics) as well as the actual teaching context in which students worked (i.e., effort invested in specific types of activities). For all the data collection instruments, which were used and are discussed below, content- and construct-validity was ensured by both the practitioner conducting each of the action research studies, as well as “external reviewers”, namely the researchers (authors of this paper) supporting the practitioners during the action research studies.

Regarding RQ1, students’ cognitive learning outcomes were measured and evaluated based on a series of assessment tests. These tests were identical between the experimental and control groups and were delivered at specific time intervals throughout each course. More specifically, an initial diagnostic test was delivered prior to the beginning of each course, to assess students’ prior knowledge on the subject matter knowledge. Each test contained ‘closed’ questions (including true – false questions, multiple choice quizzes) as well as open-ended questions (short answer and concept maps). The students’ scores on these diagnostic tests were used to create three performance-based clusters, namely low-medium-high performers. These clusters were utilized to enrich the findings of the research questions, namely to provide deep insights on how the FCM-enhanced blended learning environment affected students of different levels of prior cognitive outcomes. Fig. 2 depicts the cardinality of students assigned to each performance-based cluster for each of the three courses.

The remaining three tests were correspondingly delivered after the end of the second or third week, after the end of the sixth week and, finally, after the eighth week of the courses. All tests were assessed in a 20-point scale, following the Greek National Curriculum standards.

Regarding RQ2, students’ Satisfaction was measured using the ‘Satisfaction’ subscale of the widely used and standardized Instructional Materials Motivation Survey (IMMS) (Keller, 2010). For each of the three studies, the internal consistency reliability of the ‘Satisfaction’ questionnaire was positively evaluated using the Cronbach’s alpha coefficient (0.74 < α < 0.76).

Regarding RQ3, data regarding each of the three dimensions of Self-Determination Theory were measured using both students’ self-reported data (through questionnaires) as well as data collected through the practitioners’ observations in each of the action research. The student-reported data were collected on a weekly basis, whereas the practitioners’ observations were captured daily (but were aggregated and analysed also on a weekly basis for consistency). More specifically:

- The Competence dimension was measured using a 4-item questionnaire which is presented in Appendix 1. The internal
consistency reliability of the ‘Competence’ questionnaire was positively evaluated using the Cronbach’s alpha coefficient (0.714 < \alpha < 0.764).

- The Autonomy dimension was measured using (a) a 4-item questionnaire (Appendix 1 presents the related questionnaire items) and (b) data describing the time invested on the engagement of students in learning activities related to hands-on practice in the classroom, as captured by the practitioners’ observations following the widely-used teacher journal technique (Altrichter et al., 2008). The two types of data were jointly normalized using feature scaling to produce a single 5-point grade for each student in all studies. Regarding the internal consistency reliability of the ‘Autonomy’ questionnaire, it was positively evaluated using the Cronbach’s alpha coefficient (0.793 < \alpha < 0.822).

- The Relatedness dimension was measured using (a) data describing the level of engagement of students in collaborative learning activities in the classroom (captured by the practitioners’ observations) as well as (b) a scoring rubric completed by the practitioners assessing the contribution of students in collaborative activities. Appendix 1 presents the related items, which were jointly normalized using feature scaling to produce a single 5-point grade for each student.

3.5. Data analysis

To answer each of the three Research Questions and implement the Reflect phase in each study, a specific set of data analysis methods was employed, as follows.

Regarding RQ1, independent sample t-tests were used to investigate the impact of the blended learning environment supported by the FCM on students’ cognitive learning outcomes. Furthermore, ANCOVA tests were performed in order to re-validate these findings by accounting for students’ prior cognitive outcomes (based on the diagnostic test results) and generating more robust results, namely removing potential bias in the findings derived from students’ having very dissimilar prior levels of cognitive outcomes. Finally, ANOVA tests were used to investigate the impact of FCM on the performance-based student clusters.

Regarding RQ2, independent sample t-tests were used to investigate the impact of the blended learning environment supported by the FCM on students’ level of satisfaction. Also, ANCOVA tests were performed to re-validate these findings by accounting for students’ levels of satisfaction at the beginning of the course. Finally, ANOVA tests were used to investigate the impact of FCM on the performance-based student clusters.

Regarding RQ3, independent sample t-tests were used to investigate the impact of the blended learning environment supported by the FCM on each dimension of students’ self-determination. ANCOVA tests were performed to re-validate these findings by considering students’ prior levels in each dimension of Self-Determination determination at the beginning of the course. Finally, paired-sample t-tests and ANOVA tests were used to investigate the impact of FCM on different performance-based student clusters.

All the aforementioned data analysis tasks were performed using the IBM “Statistical Package for the Social Sciences” (SPSS), version 23 for Windows.

4. Results

4.1. Results on students’ learning outcomes (RQ #1)

Research Question #1 aimed to investigate whether the exploitation of FCM would contribute to improving students’ learning outcomes compared to a control group, and furthermore, what would be the impact of FCM on different performance-based student clusters.

Figs. 3–5 depict the results of the students’ assessment tests (mean values) for each student group across the three studies, respectively.

As the data from Figs. 3–5 indicate, the experimental groups in all studies showed a higher increase in their learning outcomes compared to their control counterparts. To further validate this conclusion and also explicitly take into account the groups’ prior competences, both t-test and ANCOVA analyses were employed.

Table 1 depicts the independent samples t-test results regarding students’ cognitive learning outcomes between the experimental

![Fig. 3. Results of student assessment tests for Study #1 (labels in columns refer to Mean (SD)).](image)

![Fig. 4. Results of student assessment tests for Study #2.](image)

![Fig. 5. Results of student assessment tests for Study #3.](image)
and control groups for all three FCM studies. In all cases, Levene's test for equality of variances could not reject the hypothesis of equal variances.

As Table 1 shows, in all three studies, there is no statistically significant difference in the students' cognitive learning outcomes between groups regarding the diagnostic test. This finding provides initial proof that the experimental and control groups had similar initial proof that the experimental and control groups had similar prior level of cognitive outcomes for all studies. The same applies for Test #1 in all studies, namely that there was no statistical difference among the students of different groups, even though the students in the experimental groups performed higher, on average. However, the remaining data from Table 1 show that as all courses progressed, the impact of the FCM model was becoming more evident. In particular, regarding test #2 and test #3, the data from all three studies showed a statistically significant difference in favor of the experimental groups compared to their control group counterparts.

Additionally, ANCOVA tests were performed to re-validate the findings and investigate whether the cognitive learning outcomes between groups were improved in a statistically significant manner, accounting for the students' grades in the diagnostic test (i.e., their prior level of cognitive outcomes). The assumption of homogeneity of regression was verified for all cases. Table 2 depicts the results of the ANCOVA analyses.

As Table 2 shows, in all three studies, the data suggest that students' prior learning outcomes did not influence the positive findings on the impact of FCM. In particular, even after accounting for these student characteristics, the performance improvement of students of the experimental groups was still statistically different (and higher) compared to the control group counterparts.

Finally, ANOVA tests were used to investigate how FCM impacted the learning outcomes of the different performance-based student clusters. This study of learning performance increase was based on the difference between the students' performance in the diagnostic and the assessment test #3. More specifically, for all three studies, the data showed a significant effect for students in the experimental group, but not for the control group, i.e., significant differences among performance-based clusters were only found within the experimental group. These findings corroborate initial evidence outlined in prior works (Katsa et al., 2016; Kostaris et al., 2017) and set out an interesting pattern which is deemed worthy for further investigation. More specifically, it is evident that low performers reaped the most benefits from the implementation of FCM, whereas medium and high performers showed less improvement, albeit significantly higher than their control group counterparts. Based on this, it can be argued that FCM-enhanced blended learning environments can be utilized to support students facing difficulties (in terms of learning outcomes) and contribute to raising their capacity to meet the ‘learning pace’ of their classmates, which could potentially lead to more consistently high-performing cohorts of students.

### 4.2. Results on students’ satisfaction (RQ #2)

Research Question #2 aimed to investigate whether the FCM would result in enhancing the satisfaction of students during the learning process and, moreover, whether students from different performance-based clusters would be impacted on a different rate. Table 3 depicts the results regarding students' satisfaction between the experimental and control groups for all three FCM studies. In all cases, Levene's test for equality of variances could not reject the hypothesis of equal variances.

As Table 3 shows, a statistically significant difference was

---

### Table 1

Independent samples t-test results for cognitive learning outcomes.

<table>
<thead>
<tr>
<th>Assessment Tests</th>
<th>Study #1</th>
<th>Study #2</th>
<th>Study #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic Test</td>
<td>-0.749(44)</td>
<td>-0.082(38)</td>
<td>-0.518(40)</td>
</tr>
<tr>
<td>Assessment Test #1</td>
<td>-1.278(44)</td>
<td>-0.55(38)</td>
<td>1.41(40)</td>
</tr>
<tr>
<td>Assessment Test #2</td>
<td>-5.32(44)**</td>
<td>-2.83(38)**</td>
<td>-2.51(40)**</td>
</tr>
<tr>
<td>Assessment Test #3</td>
<td>-3.12(44)**</td>
<td>-2.86(38)**</td>
<td>-2.69(40)**</td>
</tr>
</tbody>
</table>

Significant at the 0.05 level, **significant at the 0.01 level.

---

### Table 2

ANCOVA analysis results for RQ#1.

<table>
<thead>
<tr>
<th>Studies</th>
<th>Test #1</th>
<th>Test #2</th>
<th>Test #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study #1</td>
<td>F(1,43) = 3.83**</td>
<td>F(1,43) = 55.97**</td>
<td>F(1,43) = 16.43**</td>
</tr>
<tr>
<td>Study #2</td>
<td>F(1,37) = 20.92**</td>
<td>F(1,37) = 19.11**</td>
<td>F(1,37) = 49.98**</td>
</tr>
<tr>
<td>Study #3</td>
<td>F(1,39) = 22.44**</td>
<td>F(1,39) = 13.92**</td>
<td>F(1,39) = 27.37**</td>
</tr>
</tbody>
</table>

**significant at the 0.05 level, **significant at the 0.01 level.

---

### Table 3

Independent samples t-test analysis results for satisfaction.

<table>
<thead>
<tr>
<th>Studies</th>
<th>Satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study #1</td>
<td>CG [Mean (SD)] 3.62(0.41) EG [Mean (SD)] 4.47(0.22) t(df) 4.57(44)**</td>
</tr>
<tr>
<td>Study #2</td>
<td>CG [Mean (SD)] 3.71(0.55) EG [Mean (SD)] 4.38(0.34) t(df) 4.57(44)**</td>
</tr>
<tr>
<td>Study #3</td>
<td>CG [Mean (SD)] 3.55(0.44) EG [Mean (SD)] 4.47(0.22) t(df) 4.57(44)**</td>
</tr>
</tbody>
</table>

**significant at the 0.01 level, CG: Control Group, EG: Experimental Group.**
detected regarding students' satisfaction between the experimental and control groups. This consistent pattern across all studies provides evidence that the FCM allowed practitioners to create a more appealing learning environment for their students, which also nurtured their sense of accomplishment and could provide the incentives to sustain their motivation throughout a wider series of courses or curriculum.

Furthermore, an ANCOVA analysis was performed so as to revalidate these findings by explicitly accounting for students' prior levels of satisfaction (at the beginning of the course). The results of the ANCOVA analysis are presented in Table 4. As Table 4 depicts, the findings regarding the statistically significant difference among the two student groups hold, even when accounting for students' prior levels of satisfaction.

Finally, in order to reveal potential differences in the impact of the FCM on the different performance-based student clusters, ANOVA tests were performed. The results from all three studies were consistent and followed a common pattern. In particular, ANOVA tests were performed. The results from all three studies were found between the low- / high- performers' clusters and the medium- performers' clusters in all studies.

Similar to the findings from RQ #1, the evidence drawn regarding students' satisfaction also argue in favor of the capacity of the FCM to primarily improve the dispositions of low-performing students. Even though all student clusters benefitted from the FCM (as the comparison with the control group suggests), it is considered important that the changes induced to the learning process due to the FCM led low performers to find more contentment and fulfillment in their learning. Such evidence call for additional work to not only corroborate these findings, but also to identify the specific aspects of FCM that led to them and allow practitioners and researchers to replicate them in additional contexts.

4.3. Results on students' self-determination elements (RQ #3)

Research Question #3 aimed to provide insights on whether the exploitation of FCM can contribute to enhancing students' self-determination during learning, namely in terms of students' sense of competence, autonomy and relatedness. Table 5 depicts the results regarding the dimensions of self-determination for students across the experimental and control groups for all three FCM studies during the last week of the course. As with all previous analyses, the Levene's test for equality of variances could not reject the hypothesis of equal variances.

As Table 5 depicts, there was a consistent pattern in the findings across all studies, regarding students' dimensions of self-determination. More specifically, the data analysis indicates that the use of FCM provided a nurturing environment in which students were able to better fulfill their needs regarding competence, autonomy in their learning as well as relatedness. Furthermore, when compared to the corresponding results from the control groups in each study (Fig. 8 for descriptive statistics), it is evident that the FCM provided strong added value, which are reflected in the statistically significant differences reported for all self-determination dimensions.

In particular, the findings suggest that the FCM fulfilled

### Table 4

<table>
<thead>
<tr>
<th>Studies</th>
<th>ANCOVA analysis results for satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study #1</td>
<td>F (1,43) = 16.496**</td>
</tr>
<tr>
<td>Study #2</td>
<td>F (1,37) = 22.792**</td>
</tr>
<tr>
<td>Study #3</td>
<td>F (1,39) = 12.668**</td>
</tr>
</tbody>
</table>

**significant at the 0.01 level.

![Fig. 7](image1) Descriptive statistics of the Bonferroni post-hoc results regarding satisfaction for competence-based clusters in the experimental groups — RQ#2 (Labels in the columns refer to Mean (SD)).

![Fig. 8](image2) Descriptive statistics on students' dimensions of self-determination in the three studies (Labels in the columns refer to Mean (SD)).

### Table 5

<table>
<thead>
<tr>
<th>Dimensions of self-determination</th>
<th>Study #1</th>
<th>Study #2</th>
<th>Study #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competence</td>
<td>-7.98(44)**</td>
<td>-3.69(38)**</td>
<td>-9.22(40)**</td>
</tr>
<tr>
<td>Autonomy</td>
<td>-12.32(44)**</td>
<td>-4.35(38)**</td>
<td>-7.69(40)**</td>
</tr>
<tr>
<td>Relatedness</td>
<td>-114.48(44)**</td>
<td>-36.40(38)**</td>
<td>-112.22(40)**</td>
</tr>
</tbody>
</table>

*significant at the 0.05 level, **significant at the 0.01 level.
students’ need for Competence, namely the need to feel capable to successfully engage in the learning process. These findings can be interpreted as being corroborating evidence to a number of existing studies highlighting the impact of FCM for improving students’ learning outcomes (e.g., Bhagat et al., 2016). Therefore, these insights can offer a potential underlying factor that explains these existing findings, namely that the FCM can be used to create a supportive environment that builds the students’ confidence towards successfully engaging with the learning process. It can be argued that this effect comes as a result of the principles of FCM, i.e., the better exploitation of classroom-based time for both engaging with (collaborative) activities aimed to improve students’ competence as well as providing feedback and scaffolds by the teacher during this process.

Regarding students’ need for Autonomy, the FCM effectively supported students’ need to be engaged with tasks in an autonomous manner within a context that is relevant to them. It is argued that this level of autonomy was allowed in the learning environments created by the FCM, since students could invest more time on hands-on activities and peer-/teacher- collaboration instead of being exposed to teacher-led lecturing which would be restricting in terms of autonomy.

The ANCOVA analysis regarding students’ need for Relatedness also argue that the capacity of the FCM to free-up classroom time for students’ active engagement with collaborative activities scaffolded by their classmates and their teacher has indeed a significant impact on their internal sense of being part of a social context that supports and promotes their learning.

Additionally, an ANCOVA analysis was employed to account for students’ prior levels in each dimension of self-determination theory (at the beginning of the course). The results of the ANCOVA analysis (Table 6) show that even when accounting for students’ prior levels, the FCM influenced a statistically significant difference between the two student groups in all three studies.

Finally, a follow-up analysis of the three dimensions of self-determination was conducted, on the performance-based clusters of students in the experimental groups in each study. These analyses were performed to study how the FCM impacted different clusters of students of the experimental groups in terms of the three dimensions of self-determination theory.

The improvement of all clusters in terms of the SDT dimensions between the beginning and the end of the course was investigated using paired-samples t-tests. Table 7 presents the results of the paired samples t-test for each performance-based cluster against the three SDT dimensions.

As Table 7 depicts, all student clusters significantly improved their level of SDT dimensions throughout the FCM-enhanced courses. Combined with the insights from Tables 5 and 6, a consistent pattern of findings is elicited, providing initial evidence that the FCM not only provided a nurturing environment for students compared to the control counterparts, but also in terms of their own individual improvement since the start of the courses.

Furthermore, data regarding the final week of the course were further scrutinized using ANOVA tests, to unravel concluding insights after the completion of the course on students’ SDT dimensions. To allow easier presentation of findings, the descriptive statistics for each student cluster are presented in Table 8, to inform the interpretation of the Bonferroni post-hoc test results, which are presented below.

More specifically, for all three studies the ANOVA test revealed statistically significant differences between performance-based student clusters regarding the need for Competence ([F(2,20) = 5.180, p = 0.015] for Study #1, [F(2,17) = 21.453, p = 0.02] for Study #2 and [F(2,17) = 3.330, p = 0.05] for Study #3). The Bonferroni post-hoc test allowed additional insights regarding which clusters showed these significant differences. In all cases, the significant differences were identified between the low-performing student cluster and the high-performing student cluster (see Table 8 for descriptive statistics). This means that even though the FCM was significantly beneficial for all student clusters, the low-performing students reported the greatest level of benefit at the end of the course. This can be perhaps attributed to the nature of the activities that students engaged with during the classroom sessions. In particular, the shifting of the focus of classroom sessions on hands-on activities, scaffolded by both peers and the teacher. The data suggest that the students of the low-performing cluster regarded this novel nurturing environment as highly beneficial for them in terms of perceived competence. On the other hand, the data suggest that medium/high-performing students, while also significantly improving their levels of Competence compared the start of the course, probably already had considerably high levels of Competence independently from the exploitation of FCM.

These findings provided interesting insights that corroborate the conclusions from RQ1. Capitalizing on these-aggregated results, it is reasonable to argue that the FCM can not only foster enhanced student learning outcomes, especially for low-performing students, but can also nurture a more internal and overarching improvement on these students’ capacity, by building their self-confidence to engage in the learning process.

Furthermore, regarding the need for Autonomy, the ANOVA tests revealed a similar pattern of findings. More specifically, all three studies reported statistically significant differences, namely [F(2,20) = 5.150, p = 0.016] for Study #1, [F(2,17) = 20.085, p = 0.05] for Study #2 and [F(2,17) = 4.162, p = 0.032] for Study #3. Again, the Bonferroni post-hoc analysis showed that the low performing students reported the greatest level of benefit at the end of the course. On the other hand, the medium- and high-performing clusters appear to have more moderate concluding opinions regarding the added value of FCM, even though the data suggest that they also showed a statistically significant improvement in the level of Autonomy compared to the start of the course.

These findings are very promising, in the sense that low performing students would perhaps be expected to seek or perceive less levels of autonomy in the learning process. However, as the data suggest, they consistently reported that the FCM allowed them to work more freely and to view the learning activities as interesting to them. This can be perhaps attributed to the fact that the use of FCM explicitly engaged these students in scaffolded hands-on activities requiring their active engagement, possibly increasing the relevance of the course to their interests and making clearer the competence gains they could reap. These initial insights are deemed worthy to be further investigated in future works, as it is discussed in the final section. Furthermore, the more moderate concluding level reported for medium-/high-performers also constitutes a significant finding. Despite the evident benefit of the FCM (Table 2), it appears that medium-/high-performing students reached a plateau in their improvement of Autonomy more quickly compared to the low-performing students. This finding can be attributed to the assumption that these students had a narrower space for improvement and covered it before the end of the course.
was 376 dimensions. These regarding the impact of FCM on students' self-determination dimensions. Present between the low performers and the high performers. ¼ p of the classroom-based sessions (i.e., in activities with their peers. When such activities were a minor part appear to have appreciated the capacity to engage in collaborative forming students commonly took in such activities. Therefore, it is believed that, even though the latter two clusters also significantly enhanced their level of Relatedness (Table 7), their concluding level was ‘normalized’ against the increased level of the low performing students. This finding is promising and suggests a better ‘distribution’ among students’ SDT dimensions across different studies and subject domains, while at the same time significantly improving the individual levels in each dimension for all students. As aforementioned, these initial findings should provide the basis for additional investigations in future research.

5. Conclusions and Future Work

The paper presented a consolidated analysis of three FCM implementations in the context of K-12 education, in order to extend the current body of knowledge and reveal how the FCM can not only influence students’ cognitive learning outcomes, but also build their level of satisfaction from the learning process and fulfill their internal motivational needs.

The overall insights from the analysis are promising and reveal a consistent pattern. More specifically, the results indicated that the incorporation of the FCM in the teaching and learning process led to a statistically significant increase in the cognitive learning outcomes of students. This type of insights has been largely reported in prior works (e.g., Aidinopoulou & Sampson, 2017; Kong, 2014; Tanner & Scott, 2015), therefore this study provided corroborating evidence to further extend and support this knowledge pool. In addition, also corroborating initial prior results (e.g., Kostaris et al., 2017), it was found that the largest increase in performance was reported for the low performing students. The fact that such results were drawn across different subject domains, argues that the FCM could provide an effective method to raise the performance of students facing difficulties in ‘traditional’, face-to-face educational contexts and, therefore help teachers and schools both improve the learning conditions offered to students as well as better meet potential external accountability criteria.

Furthermore, regarding students’ satisfaction, the analysis of data provided interesting evidence from a two-fold perspective. First, it was consistently found across all three studies that the students exposed to the experimental conditions of FCM had a significantly higher level of satisfaction compared to their control group counterparts. This consistent pattern suggests that FCM can be exploited to create learning environments that foster students’ sense of accomplishment and to drive an internal improvement of

Table 7
Paired samples t-test for performance-based student clusters in the experimental groups in terms of self-determination dimensions before and after the courses.

<table>
<thead>
<tr>
<th>Studies (for experimental groups)</th>
<th>Competence (t(df))</th>
<th>Autonomy (t(df))</th>
<th>Relatedness (t(df))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study #1 Low Performers</td>
<td>6.276(8)**</td>
<td>6.378(8)**</td>
<td>6.796(8)**</td>
</tr>
<tr>
<td>Medium Performers</td>
<td>6.222(5)**</td>
<td>4.477(5)**</td>
<td>7.702(5)**</td>
</tr>
<tr>
<td>High Performers</td>
<td>3.650(7)**</td>
<td>3.314(7)**</td>
<td>–2.319(7)**</td>
</tr>
<tr>
<td>Study #2 Low Performers</td>
<td>5.601(6)**</td>
<td>6.033(6)**</td>
<td>5.315(6)**</td>
</tr>
<tr>
<td>Medium Performers</td>
<td>2.703(7)**</td>
<td>2.657(7)**</td>
<td>10.791(7)**</td>
</tr>
<tr>
<td>High Performers</td>
<td>10.235(4)**</td>
<td>12.797(4)**</td>
<td>6.689(4)**</td>
</tr>
<tr>
<td>Study #3 Low Performers</td>
<td>4.899(4)**</td>
<td>8.729(4)**</td>
<td>2.625(4)**</td>
</tr>
<tr>
<td>Medium Performers</td>
<td>3.249(8)**</td>
<td>8.164(8)**</td>
<td>7.896(8)**</td>
</tr>
</tbody>
</table>

*significant at 0.05, **significant at 0.01, Data were normally distributed.

Table 8
Descriptive statistics of performance-based student clusters in the experimental groups in terms of self-determination dimensions.

<table>
<thead>
<tr>
<th>Studies (for experimental groups)</th>
<th>Competence [Mean (SD)]</th>
<th>Autonomy [Mean (SD)]</th>
<th>Relatedness [Mean (SD)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study #1 Low Performers</td>
<td>3.93(0.35)</td>
<td>4.55(0.18)</td>
<td>4.85(0.32)</td>
</tr>
<tr>
<td>Medium Performers</td>
<td>3.75(0.27)</td>
<td>4.39(0.18)</td>
<td>4.78(0.02)</td>
</tr>
<tr>
<td>High Performers</td>
<td>3.44(0.29)</td>
<td>4.22(0.23)</td>
<td>4.73(0.03)</td>
</tr>
<tr>
<td>Study #2 Low Performers</td>
<td>3.96(0.54)</td>
<td>3.83(0.50)</td>
<td>4.61(0.75)</td>
</tr>
<tr>
<td>Medium Performers</td>
<td>3.86(0.52)</td>
<td>3.68(0.51)</td>
<td>4.53(0.04)</td>
</tr>
<tr>
<td>High Performers</td>
<td>3.50(0.51)</td>
<td>3.25(0.62)</td>
<td>4.47(0.05)</td>
</tr>
<tr>
<td>Study #3 Low Performers</td>
<td>4.75(0.20)</td>
<td>3.79(0.44)</td>
<td>4.77(0.05)</td>
</tr>
<tr>
<td>Medium Performers</td>
<td>4.42(0.20)</td>
<td>3.32(0.45)</td>
<td>4.70(0.03)</td>
</tr>
<tr>
<td>High Performers</td>
<td>4.45(0.24)</td>
<td>3.21(0.31)</td>
<td>4.69(0.01)</td>
</tr>
</tbody>
</table>
the incentives to participate in the learning process. Second, a deeper analysis of data within the different performance-based student clusters in the experimental group revealed that the low performing students had significantly higher levels of satisfaction compared to medium/high performers. When viewing this finding in conjunction with the previous results on students’ learning outcomes, it is reasonable to argue that the FCM can provide the means to improve students’ performance and experiences in a holistic manner, primarily allowing supporting low performing students to change their dispositions towards the learning process and become more content with participating in and completing it.

Regarding students’ self-determination, the findings from the three FCM implementations also showed a consistent and promising pattern. In particular, students exposed to FCM-enhanced blended environments reported significantly higher fulfillment of their ‘self-determination’ needs. They were supported to meet their needs for autonomy, mainly through the capacity to engage in collaborative activities primarily led by themselves and their peers (and only supported by their teacher). Additionally, it is argued that the provision of scaffolding by their teacher and the engagement with hands-on practices contributed to their enhanced sense of competence, making them more confident to engage and complete the challenges of the learning process. To further corroborate this conclusion, the students’ sense of relatedness was also significantly higher for those exposed in the experimental conditions, also a potential outcome of the capacity to invest more time and effort in collaborating within a peer- and mentor-supported social context, instead of (mainly) participating in passive lecturing with minimal participation.

Lastly, mirroring the insights previously discussed on students’ satisfaction, it was found that the low-performing students of the experimental groups reported the highest levels in all self-determination dimensions at the end of the course. The capacity to engage more deeply in collaborative and hands-on activities appears to have had a longer impact on low-performing students, across the full length of the course. On the other hand, the data suggest that medium- and high-performing students perhaps had a narrower window for improvement due to pre-existing high levels in all SDT dimensions. Additionally, it is also possible that their level of SDT towards the end of the course were normalized against the emerging level of the low-performing students (e.g., in the case of participation in collaborative activities). However, consistently across the studies, it was evident that all student clusters showed a statistically significant increase across all SDT dimensions between the start and the end of the courses. This finding completes a promising streak of insights that the FCM can be used to effectively support students (especially low performers) alleviate their perceived capacity to successfully engage in the learning process and build positive perceptions through collaborative and self-/peer-guided work.

Future research in this agenda should aim to further extend the reported findings and address the main limitations of this work. More specifically, the generalizability of the results of this work must be carefully approached, since they were derived based on data from small-scale (albeit thoroughly designed) studies. This limitation calls for the need to conduct more longitudinal studies, comprising larger sample sizes and wider periods of investigation. Also, such studies could aim to corroborate and further explain the promising initial results regarding the positive effects of FCM primarily on low-performing students as well as the more moderate impact on medium-/high-performers. Second, the utilized data collection methods (namely, questionnaires and teacher journal observations) although commonly used in the literature, may present common method biases. Therefore, additional research is called for to complement these findings, building on a wider range of data sources, including in-depth student and teacher interviews, interaction analyses and behavioral patterns. Also, these studies, capitalizing on the wide range of data collected, should complement the initial findings of this work and investigate deeper the mechanisms connecting students’ performance and internal motivational needs for effectively engaging in the learning process within blended environments.

Finally, future work should also build on educational innovations focusing on supporting data-driven appraisal and improvement of teaching and learning practice using digital technologies. The emerging fields of Teaching and Learning Analytics (Sergis & Sampson, 2017) presents such an innovation. More specifically, Teaching and Learning Analytics refer to methods and tools used to facilitate evidence-based reflection on teaching practice based on the analysis of student educational data. The added-value of these emerging technologies is that they combine the potential of (a) Teaching Analytics, for analyzing the teaching practice (e.g., Sergis & Sampson, 2016) and (b) Learning Analytics, for measuring, collecting, analysing and reporting on learners’ educational data. Thus, they can build on a rich and complementary data pool, so as to support teachers reflect on and improve their practice to enhance the provision of personalized learning experiences to their students.

Acknowledgments

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Appendix

Data types for the Autonomy dimension of SDT:

- Questionnaire items for the Autonomy dimension of SDT (5-point Likert scale)
  1. The content of this course is relevant to my interests
  2. There are explanations or examples of using the knowledge in this course
  3. The content of this course conveyed the impression to me that it is worth knowing
  4. The content of this course will be useful to me
- Teachers’ observation data regarding the time invested in conducting hands-on activities

Questionnaire items for the Competence dimension of SDT (5-point Likert scale)

1. When engaged with the course, I felt that it would be easy for me
2. As I worked on this course, I was confident that I could learn the content
3. After working on this course for a while, I was confident that I would be able to pass a test on it.

4. The good organization of the material in the course helped me be confident that I would learn this material.

Data types for the Relatedness dimension of SDT:

- Teachers’ observation data regarding the time invested in collaborative learning activities with other students.
- Teachers’ scoring data in the engagement rubric items used in the theses:
  - The student offers help to the members of their group, when needed.
  - The student contributes in whole-classroom group activities.
  - The student is actively and consistently engaged in their assigned tasks, as part of a group.

Questionnaire items for the Satisfaction variable of the study (5-point Likert scale):

1. I really enjoyed studying this course.
2. The feedback provided and the exercises helped me feel rewarded for my effort.
3. It felt good to successfully complete this course.
4. I enjoyed this course so much that I would like to know more about this topic.

References


