Kostaris, C., Sergis, S., Sampson, D. G., Giannakos, M. N., & Pelliccione, L. (2017). Investigating the Potential of the Flipped Classroom Model in K-12 ICT Teaching and Learning: An Action Research Study. *Educational Technology & Society, 20* (1), 261–273.

Investigating the Potential of the Flipped Classroom Model in K-12 ICT Teaching and Learning: An Action Research Study

Christoforos Kostaris[1,2], Stylianos Sergis[2,4], Demetrios G. Sampson[3,4*], Michail N. Giannakos[5] and Lina Pelliccione[3]

[1]15th Junior High School of Peristeri, Athens, Greece // [2]Department of Digital Systems, University of Piraeus, Greece // [3]School of Education, Curtin University, Australia // [4]Information Technologies Institute, CERTH, Greece // [5]Department of Computer and Information Science, Norwegian University of Science and Technology, Norway // xkostaris@yahoo.gr // steliossergis@iti.gr // demetrios.sampson@curtin.edu.au // michailg@idi.ntnu.no // L.Pelliccione@curtin.edu.au

[*]Corresponding author

ABSTRACT

The emerging Flipped Classroom approach has been widely used to enhance teaching practices in many subject domains and educational levels, reporting promising results for enhancing student learning experiences. However, despite this encouraging body of research, the subject domain of Information and Communication Technologies (ICT) teaching at K-12 education has not yet been explicitly researched. This is a considerable shortcoming given (a) the globally acknowledged need to effectively design and deliver ICT curricula to students at all levels of school education (primary, junior and senior secondary) towards cultivation of digital competences, and (b) the recurring research evidence that the Flipped Classroom approach can enhance students' learning experiences in Science, Technology, Engineering and Math (STEM) K-12 education. Therefore, the contribution of this paper is the design and implementation of an action research for studying the effect of the Flipped Classroom approach in K-12 ICT teaching and learning. The action research employed a quasi-experimental design using experimental-control groups, from two classes (a total of 46 students) for an entire semester of the school year following the National (Greek) Curriculum in junior high school ICT studies. The results of this study provide evidence for potential advantages in students' cognitive learning outcomes related to subject domain knowledge, the exploitation of teaching time during the classroom face-to-face sessions, the students' level of motivation, as well as their level of engagement.

Keywords

Flipped classroom model, K-12 education, ICT curriculum teaching, Teaching time, Student learning outcome, Student motivation, Student engagement

Introduction

Information and Communication Technologies (ICT) curricula are a core priority of educational policies worldwide, for cultivating students' diverse digital competences (Commonwealth of Australia, 2010; US Department of Education, 2010; Eurydice, 2012). These digital competences are considered a core strand of the 21st century skillset and industry work-force requirements are shifted towards attaining and exploiting such competences (OECD, 2014). Thus, ICT educational curricula have been increasingly required to effectively cultivate student digital competences by promoting more student-centred teaching approaches (e.g., Balanskat & Engelhardt, 2015). For example, the project-based approach has been positively evaluated in the context of K-12 education as a promising method to effectively engage students in the learning process and to develop their digital competences (e.g., Wang et al., 2016; Tsai et al., 2015).

Furthermore, on top of exploiting such student-centered teaching approaches, educational innovations such as the Flipped Classroom Model (FCM) have also been studied for improving learning experiences and competences. The FCM has been proposed as a method to maximize the use of teacher-supported face-to-face classroom-based sessions towards delivering hands-on activities and individual scaffolding. To achieve this, it opts for substituting the traditional teachers' lecture with appropriately designed educational resources which can be engaged by the student in an autonomous manner (Bergmann & Sams, 2012).

The FCM has received a growing level of research attention given the promising results that showcase its capacity to enhance teaching practice and deliver (among others) better students' cognitive learning outcomes and motivation in a wide range of subjects and educational levels, including ICT and STEM (Giannakos et al., 2014). However, regarding ICT teaching, existing FCM research has been solely addressed in Higher Education, where a large body of research exists that provides positive evidence on the potential of FCM to provide enhanced student experiences. Despite this evidence, however, *no explicit focus* has yet been placed on evaluating the FCM in the context of K-12 ICT teaching. This presents an important challenge, especially considering the range of successful implementations of the FCM in other compulsory school education subjects.

Thus, the contribution of this paper is to address the aforementioned issue and evaluate the FCM within the context of K-12 ICT curriculum. More specifically, the work presents the design and implementation of an action research for evaluating the capacity of the FCM to enhance students' learning experiences from a range of perspectives, namely (a) cognitive learning outcomes, (b) distribution of different types of learning activities during the face-to-face sessions, (c) levels of motivation during the learning activities, and (d) level of students' engagement during the learning activities.

The remainder of the paper is structured as follows. The Background section defines the FCM and describes existing research work on its implementation in Higher Education to enhance students' learning experiences. The Research Methodology section presents the design and methodology of the action research. The Results section presents the findings of the action research in terms of the four research questions defined. Finally, the Discussion and Future Work section presents the conclusions drawn and outlines potential strands of further research.

Background

The Flipped Classroom Model (FCM) is an emerging blended learning model, which argues for improving the student-centered exploitation of face-to-face sessions, by minimizing teacher lecture and increasing students' active learning and collaboration (Bergmann & Sams, 2012). Teacher-facilitated face-to-face sessions can provide students with unique learning experiences through direct access to both their classmates (for collaborative activities) as well as to feedback and scaffolding by their teacher (DeLozier & Rhodes, 2016). Therefore, optimizing the exploitation of face-to-face sessions is very important towards creating more student-engaging learning experiences. To accomplish this, the FCM argues that lectures can be substituted with appropriately designed and/or selected learning materials (e.g., educational videos) which can be provided to the students for prior "home study" before the face-to-face session, in a more autonomous manner (Chen et al., 2014). Thus, classroom-based time can be directed at student-engaging learning activities.

The FCM has received a growing level of research attention in a wide range of subjects and educational levels, such as STEM and ICT (Bishop & Verleger, 2013). This growing interest is fueled by the benefits attributed to the FCM primarily in terms of enhancing cognitive learning outcomes (e.g., Love et al., 2014; Kong, 2014) and motivation (Baepler et al., 2014; Hung, 2015). Surprisingly, however, despite the significant body of research for evaluating FCM in other K-12 subjects, ICT as a subject domain has received *no explicit research attention*. This is a significant shortcoming since K-12 ICT curricula are now revisited and reformed to meet the demands for diverse digital competences for all students.

On the other hand, FCM has been investigated in the context of Computing Curricula in Higher Education, so as to enhance students' *cognitive learning outcomes*. More specifically, Gannod et al. (2008) and Amresh et al. (2013) presented positive results on using FCM in software engineering courses. In the same vein, Mason et al. (2013) investigated the FCM in an advanced ICT engineering course with a specific focus on problem solving. Hayashi et al. (2014) reported that the FCM had a positive impact on students' outcomes on programming skills. Finally, Horton et al. (2014), Reza and Baig (2015) and Jonsson (2015) also reported improvements in the cognitive learning outcomes of students in FCM-supported experimental groups compared to their control counterparts.

Apart from cognitive learning outcomes, research in FCM in Higher Education ICT teaching has also focused on students' *level of motivation and/or engagement*. More specifically, Day and Foley (2006) reported positive effects of FCM on enhancing students' motivation during an ICT course (also on their cognitive learning outcomes). Similarly, Herold et al. (2012) utilized interviews of students and instructors and highlighted that the FCM enhanced students' motivation and quantity of discussions during the sessions. Dolgopolovas et al. (2014) reported on a significant increase in students' motivation in a FCM-enhanced computer science course, which was attributed to the higher proportion of hands-on activities delivered in the face-to-face sessions (even though no explicit modelling of these activities was performed). These findings are consistent with Sureka et al. (2013), and Gehringer & Peddycord (2013), who also reported enhanced student motivation in FCM-enhanced computer science courses. Davies et al. (2013) positively evaluated the impact of the FCM to enhance student motivation, satisfaction as well as cognitive learning outcomes in an introductory course on spreadsheets (linking these findings to the time spent on different types of learning activities). Finally, Choi (2013) studied the FCM in an introductory software engineering course and concluded that the experimental group showed improvement in collaboration skills and cognitive learning outcomes.

Overall, existing works highlight a consistent pattern of findings that argue in favor of the capacity of the FCM to enhance Higher Education ICT teaching in terms of students' cognitive learning outcomes, motivation, engagement and more student-oriented exploitation of face-to-face sessions. These findings are further complemented by the students' positive perceptions on the added value of FCM to both cultivate their skills related to ICT curriculum (e.g., Tanner & Scott, 2015) as well as to enhance the overall learning experience (e.g., Fryling et al., 2015).

Therefore, based on (a) the rich body of evidence on the capacity of the FCM to enhance students' learning experiences in diverse K-12 subjects (Rahman et al., 2014; Giannakos et al., 2014), and (b) the current lack of any such evidence in relation to K-12 ICT teaching despite the promising relevant findings in the Higher Education context, a research challenge is identified. This challenge relates to investigating the potential of the FCM model to provide similar improvements in the learning experiences of students in the novel context of K-12 ICT teaching, especially considering the importance of this subject for cultivating necessary digital competences for students. Furthermore, a more holistic conceptualization of "learning experiences" is adopted by exploiting all four learning experience indicators identified in existing works (but not used in combination in any of them). This more holistic approach is important to study the impact of the FCM from a perspective that involves both student-related dimensions (namely, cognitive learning outcomes, level of student motivation, level of student engagement) and teaching-related dimensions (the types of learning activities in face-to-face classroom-based sessions).

Therefore, towards addressing this research challenge, the paper describes the design and implementation of an action research in order to evaluate the capacity of the FCM to enhance students' learning experiences in a K-12 ICT course. More specifically, the action research focused on evaluating the added value of the FCM in terms of (a) improving students' cognitive learning outcomes, (b) re-distributing the types of learning activities held during the face-to-face sessions towards including more student-centered activities, (c) enhancing students' motivation, and (d) enhancing students' engagement.

Research methodology

Action research

Action research is defined as a form of data-driven disciplined inquiry in which a practitioner (namely teacher-researcher) aims to understand, analyze and, potentially improve their practice (Cohen et al., 2007). In the context of this work, the aim was related to investigating the capacity of the FCM model to enhance ICT teaching practice in K-12 curriculum.

The action research of this work was designed following the widely used four-phase process of Lewin (1948), namely Plan, Act, Observe and Reflect. More specifically, the Plan phase related to the design of the action research in terms of research questions, methodology and evaluation protocol. Additionally, it included the educational design of the ICT course which would be delivered to the experimental and control groups. The Act and Observe phases were correspondingly addressed at implementing the action research following the methodology adopted and collecting students' educational data. Finally, the Reflect phase was related to analyzing the educational data collected towards answering the defined research questions.

In order to ensure study trustworthiness, a set of four relevant criteria were adopted from Shenton (2004):

- **Credibility (internal validity)** and **Confirmability (objectivity)** criteria were addressed by: (a) adopting well-established research methods and tools for data collection and data analysis, (b) triangulation of findings derived from diverse data sources, (c) promoting peer-scrutiny of the research process, and (d) building on previous research findings (defined in the "Background" section).
- **Transferability (external validity)** criterion was addressed by: (a) clearly defining the design aspects of the study (e.g., sample size and characteristics, data collection and analysis methods /tools and study time period), and (b) identifying and reporting study limitations.
- **Dependability (reliability)** criterion was addressed by: (a) defining and reporting on the research design and implementation methodology, (b) defining and reporting on data collection and analysis processes, and (c) appraising the study, by reporting on the results to answer specific Research Questions and elicit insights for practice and research.

Each of these criteria is further elaborated in the following sections.

Research questions

Based on the insights from the literature analysis reported in the "Background" section, the following research questions were defined:

- **RQ1:** Does the exploitation of the FCM in an ICT K-12 course (in particular, junior high school) lead to enhanced students' cognitive learning outcomes related to the subject domain compared to a traditional teaching control group?
- **RQ2:** Does the exploitation of the FCM in an ICT K-12 course (in particular, junior high school) affect the distributions of learning activity types delivered in the face-to-face sessions compared to a traditional teaching control group?
- **RQ3:** Does the exploitation of the FCM in an ICT K-12 course (in particular, junior high school) lead to enhanced students' motivation compared to a traditional teaching control group?
- **RQ4:** Does the exploitation of the FCM in an ICT K-12 course (in particular, junior high school) lead to enhanced students' engagement in learning activities compared to a traditional teaching control group?

Participants and context of study

The study was conducted over a period of a full semester (8 weeks), in the context of the 2^{nd} grade of junior high school ICT studies (equivalent to 8^{th} grade, 14 years old) within the Greek National Curriculum. The course covered introductory concepts of computing including computer hardware components and their interrelation, basic software design principles as well as information processing.

The action research was implemented with the full population of two classes (i.e., 46 students), one as the experimental group (which attended the FCM-enhanced ICT course) and the other as the control group (which attended the "traditional" ICT course). Each of the student groups comprised 23 students, with 11 boys and 12 girls.

Approval and consent for conducting the action research was requested and granted by (a) the school leader (with communication to the Ministry of Education), and (b) the parents of the students selected. The students were informed that they were allowed to quit their participation at any time (also removing the relevant data collected). Finally, anonymization of all student data collected was performed throughout the implementation of the action research.

Procedure

The action research cycle comprised four phases. The first phase (Plan) was conducted from June - August 2013 prior to the start of the school year. The focus of this phase (apart from delineating the action research methodology) was focused on the educational design of the ICT course (for both the experimental and the control group). Regarding the experimental group, the Plan phase also included (a) the development and/or selection of additional learning material mainly in the form of educational videos, which would be provided to the students for their home-based study prior to the face-to-face session, and (b) the design and configuration of the online classroom environment, which would be used for delivering the learning activities outside the physical classroom. The online classroom was implemented using the Moodle Learning Management System (https://moodle.org/).

Both instantiations of the ICT course (for the experimental and the control group) were designed following the highest possible similarity in the educational design elements, in order to minimize the possibility of biased results due to vastly different teaching approaches. More specifically, the main teaching approach adopted in both groups was a project-based approach, in which students worked collaboratively to define, implement and present tangible deliverables related to the scope of each unit of the course. Furthermore, in both groups the following teaching techniques were exploited (a) the Jigsaw technique, for fostering active collaboration of students (Tahir et al., 2011) and (b) Web-quests, for promoting students' "hands-on" practice and active investigation. The assessment methods for both groups included written assessment tests (which contributed to their final grade) and collaborative project deliverables. Furthermore, the educational objectives and face-to-face session frequency and duration were similar for both student groups. The core difference between the two student groups was related to the incorporation of the FCM standpoints in terms of learning activity distribution between the face-to-face classroom-based sessions and the "homework" sessions, as follows.

Regarding the control group, the flow of learning activities for each week was initiated with the face-to-face session, in which the practitioner presented the new learning material/concepts (mainly through lecture), prior to any other learning activity. During the remaining time, the students engaged in their (collaborative) project-based activities. After each face-to-face session, the students were assigned homework to be completed at home. Regarding the experimental group, the flow of learning activities for each week included a set of learning activities, prior to the face-to-face session. During this Moodle-based pre-session, the students were primarily engaged in studying the educational material (e.g., educational videos) provided by the practitioner and self-assessment quizzes. This process was addressed at familiarizing students with the basic concepts of the follow-up face-to-face session. Therefore, the upcoming face-to-face session could be directed on (collaborative) project-based activities and feedback provision.

Following the Plan phase, the Act and Observe phases were triggered, coinciding with the 8 school weeks in which the ICT course was delivered to both student groups. Finally, the Reflect phase was implemented, capitalizing on the outcomes and data collected from the two previous phases, lasting two months.

Instruments

For the scope of this action research, data from diverse sources were collected in order to allow for effective triangulation of findings (Phillips & Carr, 2010). For all instruments used, content- and construct- validity was ensured by the practitioner as well as "external reviewers", namely (a) the "critical friend" of the practitioner (see below), and (b) the researchers (other authors) supporting the practitioner during the action research, who are experts in the field of computer science, educational research and educational technologies. Furthermore, these "external reviewers" also provided critical feedback on (a) interpreting the data collected by the practitioner (e.g., journal observations or survey data), and (b) eliciting insights from data analysis for answering the Research Questions.

Regarding **RQ1**, the students' cognitive learning outcomes were assessed through four assessment tests, common for both student groups, delivered at regular time intervals. An initial diagnostic test was delivered prior to the beginning of the action research aiming to assess students' prior knowledge from the previous grade. The test contained closed questions (true - false, multiple choice), open-ended questions (short answer) as well as the development of a concept map. The results of this initial diagnostic test were used to divide each student group in three performance-based clusters, namely low-medium-high performers (Table 1).

Table 1. Student clustering based on diagnostic tests scores (performance)

Categories of performance	Group size (*N*)	
	Control group	Experimental group
Low Performers	8	9
Medium Performers	8	6
High Performers	7	8

This clustering (further discussed in the "Results" section) was exploited during the data analysis, to offer more granulated insights on the impact of the FCM in each performance-based cluster. The remaining three tests were correspondingly delivered after the end of the second week, after the end of the sixth week and, finally, after the eighth week of the course. All tests were assessed in a 20-point scale, following the Greek National Curriculum standards.

Regarding **RQ2,** the teacher journal technique (Altrichter et al., 2008) was employed, to capture the types of activities that the students engaged with during the face-to-face sessions. The types of learning activities followed a custom typology comprising five activity types, namely teacher lecture, student-teacher interactions, student-student collaboration, "hands-on" competence-building activity and assessment activities (i.e., both standardized tests as well formative assessment). Each face-to-face session was analysed in terms of the time spent on each activity type (which were not mutually exclusive). Furthermore, the teacher journal was also populated with the practitioners' observations on students' performance as well as the observations of a "critical friend", who was a senior peer practitioner.

Regarding **RQ3,** students' motivation was measured using the standardized *Instructional Materials Motivation Survey* (IMMS) questionnaire (Keller, 2010). The IMMS questionnaire incorporates 5-point scale questions based on the ARCS motivation model, which classifies students' motivation in four dimensions, namely Attention, Relevance, Confidence and Satisfaction. More specifically, Attention is related to intriguing students' interest during the teaching process. Relevance refers to the perceived level of meaningfulness that the teaching process and material has for the students, whereas Confidence refers to the expectations of the students for succeeding in the course. Finally, Satisfaction is related to the positive attitudes of the student towards the teaching practice. The IMMS questionnaire was selected since it is a widely used and validated instrument (e.g., di Serio et al., 2013). For this study, the internal consistency reliability of the IMMS questionnaire was positively evaluated using the Cronbach's alpha coefficient ($0.88 < \alpha < 0.93$ for the four dimensions; $\alpha = 0.96$ for the overall instrument).

Finally, regarding **RQ4,** a custom engagement rubric was formulated. This rubric comprised nine 5-point Likert items, aiming to assess students' level of engagement in the face-to-face sessions. The engagement rubric was populated by the practitioner, based on their teaching journals at the end of each week. The internal consistency reliability of the instrument was positively evaluated using the Cronbach's alpha coefficient ($\alpha = 0.88$).

Data analysis

Regarding **RQ1**, the students' assessment scores on each of the three standardized tests were compared across the two groups using paired-sample and independent sample *t*-tests and ANCOVA tests. Furthermore, the assessment scores in each group were analysed against the within-group performance-based clusters in order to elicit how the FCM impacts students of different performance levels (i.e., low-medium-high performers).

Regarding **RQ2,** for each student group the exploitation of the face-to-face teaching time was analysed in terms of the typology of learning activity types using descriptive statistics. The analysis was aimed to elicit to what extent the experimental group engaged in different types of learning activities.

Regarding **RQ3,** the two student groups were compared using independent sample *t*-tests, to identify statistically significant differences in their level of motivation (based on the IMMS instrument).

Finally, regarding **RQ4,** independent sample *t*-tests were employed, to elicit statistically significant differences among the two groups in terms of engagement. Furthermore, data analysis for the within-group performance-based clusters was performed, to investigate the effect of the FCM on each cluster.

All the aforementioned data analysis tasks were performed using the IBM "Statistical Package for the Social Sciences" (SPSS), version 22 for Windows.

Results

Results regarding students' cognitive learning outcomes (RQ1)

The RQ1 aimed to investigate the added-value of the FCM on the students' cognitive learning outcomes. Figure 1 presents the results from the analysis of the students' assessment tests (mean values) for each student group.

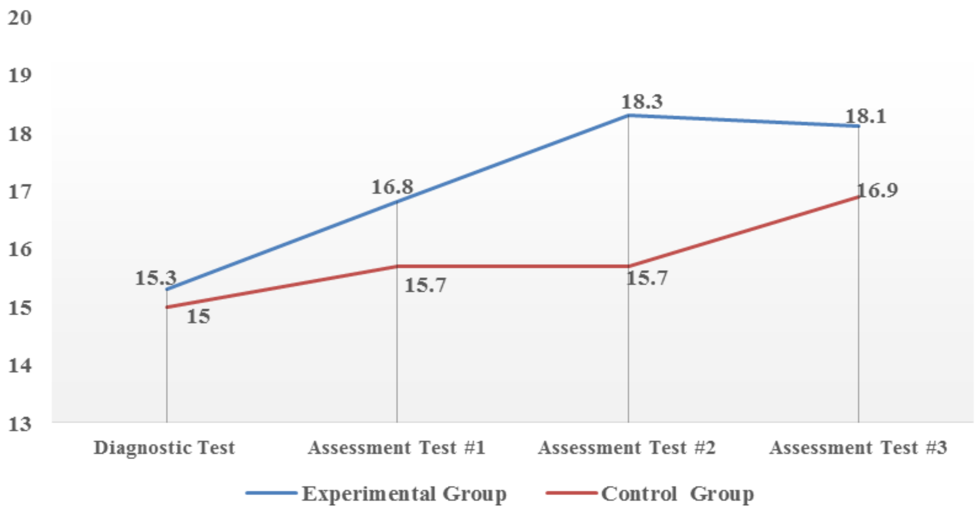

Figure 1. Results of students' standardized assessment tests

As the Figure 1 depicts, the student groups were similar in terms of prior cognitive knowledge. Beyond that point, however, the experimental group clearly outperforms the control group in all three remaining assessment tests. In order to examine whether there is a statistical significant difference, independent-sample *t*-tests were implemented for each standardized assessment test. The results are depicted in Table 2. Levene's test for equality of variances was calculated in each case and showed equal group variances.

Table 2. *t*-test comparison of standardized assessment scores between the control and experimental groups

Standardized assessment tests	Mean (*SD*)		*t*(*df*)	*p*
	Control group [*N* = 23]	Experimental group [*N* = 23]		
Diagnostic Test	15 (1.8)	15.3 (1.75)	-.749 (44)	.458
Assessment Test #1	15.7 (2.20)	16.8 (1.51)	-1.877 (44)	.067
Assessment Test #2	15.7 1.99)	18.3 (1.25)	-5.320 (44)	< .05
Assessment Test #3	16.9 (1.32)	18.1 (1.25)	-3.315 (44)	< .05

As the Table 2 depicts, there is no statistically significant difference between the groups' assessment scores on the diagnostic test, therefore the two groups were similar in this regard. Furthermore, regarding the assessment test #1, the difference between the control and experimental groups has increased from 0.3 to 1.1 points, although this difference is not considered statistically significant (Table 2). Regarding the two final assessment tests, the results of the experimental group are statistically significant compared to the control group. Thus, as the course was progressing, the benefits of the FCM were increasing on the students' performance. In order to eliminate the potential of prior knowledge bias in the results, ANCOVA tests were additionally performed to test whether the cognitive learning outcomes between groups were improved in a statistically significant manner, accounting for the students' grades in the diagnostic test. The assumption of homogeneity of regression was verified in all cases. The ANCOVA results again verified the previous findings and showed statistically significance between groups for all three tests, namely [$F(1,43) = 3.832$, $p < .05$] for assessment test #1, [$F(1,43) = 55.973$, $p < .00$] for assessment test #2 and [$F(1,43) = 16.432$, $p < .00$] for assessment test #3.

In order to further enhance the robustness of the results, the improvement of both groups was studied in terms of their corresponding diagnostic and final test results using paired-samples t-tests. The results showed that both student groups had a statistically significant improvement in their cognitive learning outcomes, namely for the experimental group ($t(df) = -9.668(22)$; $p < .00$) and the control group [$t(df) = -9.665(22)$, $p < .00$]. Therefore, the instance of the ICT course delivered to the control group was also efficient in improving the students' cognitive learning outcomes. Thus, the statistically significant difference in the improvement of the experimental group over the control group can be attributed to the exploitation of the FCM.

Finally, the data were analysed in terms of the within-group, performance-based student clusters of the experimental group. The findings are depicted in Figure 2, in terms of the percentage of improvement in the assessment scores between the initial diagnostic test and test #3.

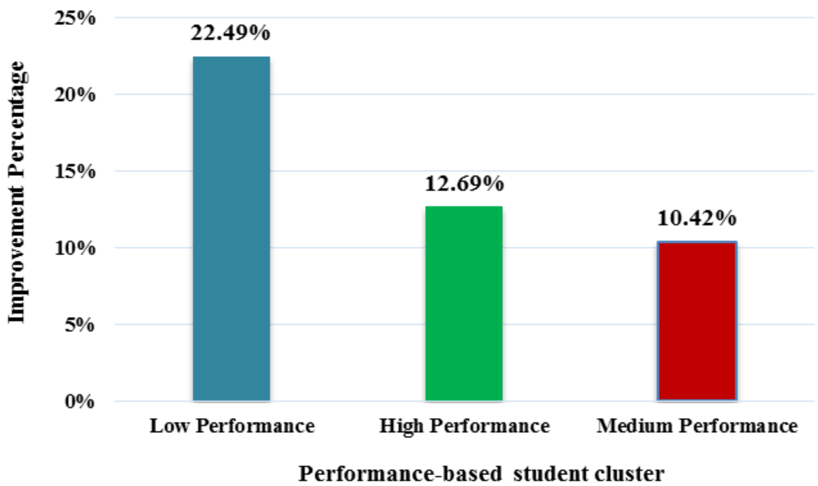

Figure 2. Assessment score improvement percentage for each student group clustering

As the Figure 2 depicts, the FCM was most beneficial for the low-performing students. This is an important finding that provides evidence for the added value of the FCM on ICT teaching to foster the improvement of students that are experiencing performance-related difficulties.

Results regarding the distribution of learning activity types in face-to-face sessions (RQ2)

The RQ2 aimed to study how the teaching time of face-to-face sessions was exploited for each group and evaluate whether the FCM can actually facilitate teachers to promote more student-centred practices. Figure 3 presents the results obtained, which are depicted as the overall mean value for the all 8 weeks.

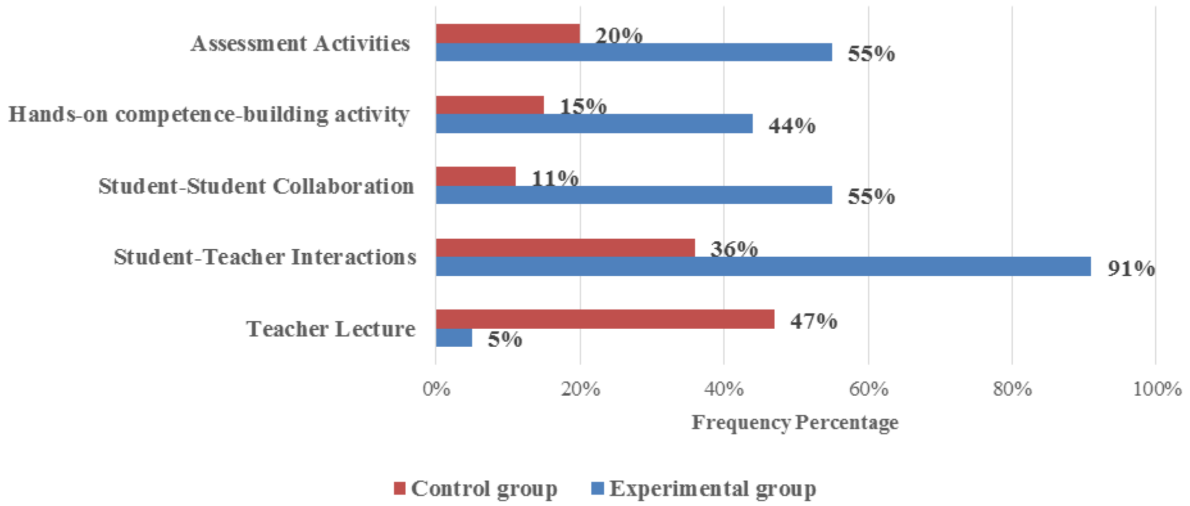

Figure 3. Percentage of learning/assessment activity frequency in face-to-face sessions for each student group

As Figure 3 depicts, teachers' lecture was the primary learning activity of the control group. This is expected since all new learning content was delivered by the teacher in-class. The control group also invested a considerable amount of teaching time in student-teacher interactions as well as on "hands-on" activities. This is due to the student-centered teaching techniques which were employed for both student groups. Student-student collaboration, however, received a very low frequency percentage, which can be considered a significant shortcoming. Finally, assessment activities for the control group were mainly related to the standardized assessment tests. On the contrary, the largest fraction of teaching time for the experimental group was invested in student-teacher interactions and student-student collaboration. This supports the standpoint that FCM can enable teachers to better exploit their teaching time. Finally, "hands-on" activity implementation was also very frequently implemented during face-to-face sessions, as well as formative assessment/feedback provision tasks (which complemented the standardized tests).

Results regarding students' level of motivation (RQ3)

The RQ3 aimed to investigate whether the exploitation of the FCM would lead to enhanced students' motivation. Table 3 presents the results obtained in terms of the four dimensions of the IMMS questionnaire.

Table 3. *t*-test comparison of motivation levels between the control and experimental groups

Motivation dimension	Mean (*SD*)		*t(df)*	*p*
	Control group [*N* = 23]	Experimental group [*N* = 23]		
Attention	3.6 (0.32)	4.5 (0.24)	10.526 (44)	< .00
Relevance	3.5 (0.28)	4.25 (0.32)	9.183 (44)	< .00
Confidence	3.69 (0.35)	4.40 (0.24)	7.984 (44)	< .00
Satisfaction	3.62 (0.42)	4.47 (0.32)	8.731 (44)	< .00

As the Table 3 depicts, there is a consistent pattern of statistically significant higher levels of improvement for the experimental group compared to the control group. This finding suggests that students considered that the FCM approach enhanced not only their satisfaction for the teaching practice, but also their own conceptualization of the ICT course and the learning process. Therefore, students in the experimental group were more confident in successfully engaging with the learning activities (Confidence dimension) and were also more intrigued by the manner in which the teaching process was delivered (Attention). Finally, the results from the Relevance dimension indicate that the students viewed the FCM-enhanced ICT course as being more relevant to their own interests.

Results regarding students' level of engagement (RQ4)

The RQ4 aimed to investigate whether the exploitation of the FCM would lead to enhanced students' engagement. Table 4 presents the results obtained from the independent samples *t*-test, based on the mean scores of engagement for each week of the study.

Table 4. *t*-test comparison of engagement levels between the control and experimental groups

	Mean (*SD*)		*t(df)*	*p*
	Control group [*N* = 23]	Experimental group [*N* = 23]		
Level of engagement	3.61 (0.81)	4.01 (0.31)	3.230 (44)	< .00

As the Table 4 depicts, there is a statistically significant difference between the two groups, in favor of the experimental group. It is evident that the FCM was beneficial not only for maintaining students' level of engagement throughout the ICT course, but also for increasing it as the course delivery progressed. Furthermore, in order to investigate the level of engagement and its progress throughout the 8-week period, data from the within-group student clusters were analyzed and are presented in Figure 4 (control group) and Figure 5 (experimental group).

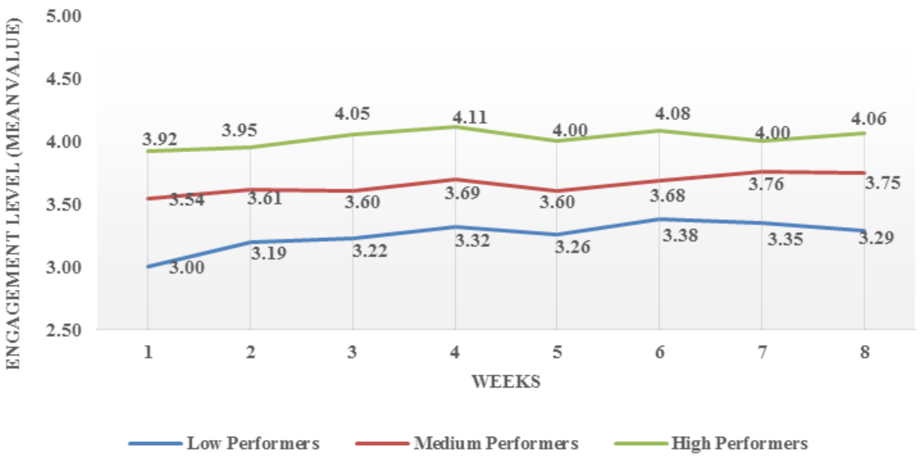

Figure 4. Mean values for the Engagement Level of the control group

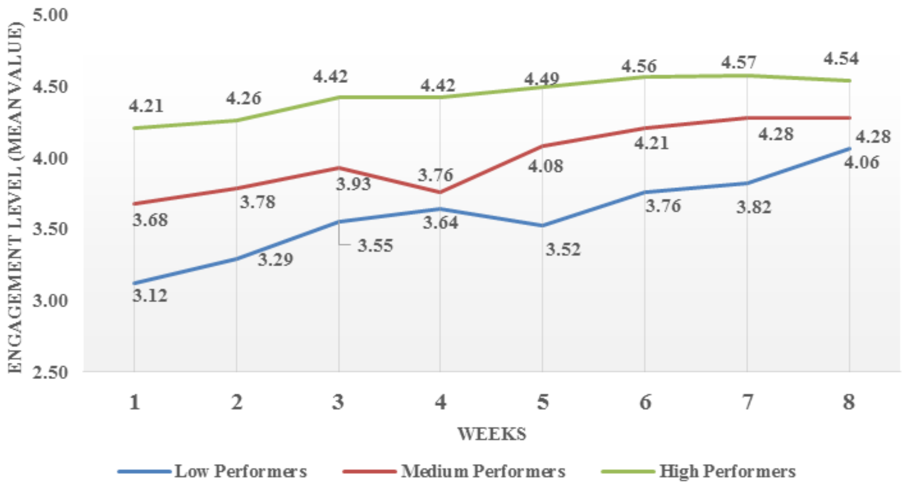

Figure 5. Mean values for the Engagement Level of the experimental group

As the Figure 4 and Figure 5 depict, students in both groups showed a continuous increase in engagement, with a larger improvement margin in favor of the experimental group clusters. Moreover, both figures show a small decline pattern in students' engagement levels between weeks #3 and #4 which is consistently reversed between weeks #5 and #6. These patterns can be explained in conjunction with the placements of the standardized assessment tests #2 and #3, which were delivered on week #2 and week #6 correspondingly.

Furthermore, regarding the experimental group, a significant finding is that the low performers cluster was most benefited (Figure 5). More specifically, the low performers showed an overall increase of 30.1% in their engagement level, compared to a 16.3% increase of the medium performers and a 7.8% of the high performers. Thus, it is argued that the FCM not only enhanced engagement for all students, but also provided the best benefits for the students that struggle in terms of performance. This finding is consistent with the findings from RQ1, namely that low performers were also most benefited from the FCM in terms of cognitive learning outcomes improvement.

Discussion and future work

The paper presented the design and implementation of an action research for the first attempt to evaluate the FCM in the context of K-12 ICT teaching. Based on a literature review on existing works in Higher Education, four research questions were defined. The added value of the action research is twofold, namely (a) it investigated the potential of FCM in the previously unexplored educational context of K-12 ICT teaching, and (b) it adopted a more holistic conceptualization of students' learning experience, by combining existing approaches to model it in relevant works.

The overall insights from the action research are highly promising and consistent with the findings of similar works in the context of Higher Education. 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 is a commonly reported benefit of the FCM in Higher Education ICT education, and this study provided evidence to extend this statement to the K-12 context, as well. Another added-value finding of this work was that the low performers were identified as the group that experienced the largest improvement. This can be attributed to the capacity of the students to receive formative feedback and scaffolding during face-to-face sessions, both from their teacher as well as from their classmates when engaging in collaborative activities.

Furthermore, the experimental group showed statistically significant increase in their *motivation*. This finding signifies that students' satisfaction and interest in the ICT course was enhanced and, moreover, that students were able to link the learning process to their own interests and improve their sense of accomplishment. These findings are consistent with existing works, e.g., Gehringer and Peddycord (2013), and Dolgopolovas et al. (2014). Regarding *students' engagement*, the results provide useful new evidence considering that this aspect had previously received very little explicit attention (e.g., Herold et al., 2012). More specifically, the results indicated that the FCM provided two main benefits: (a) the students were significantly more engaged throughout the course with a continuously increasing trend, and (b) within-group cluster analysis in the experimental group revealed that the low performers had the largest percentage of improvement. These benefits (as well as the evidence regarding student motivation) can be largely attributed to the *better exploitation of face-to-face sessions* that the FCM promoted. As the analysis of the delivered types of teaching and learning activities indicated, the FCM allowed the practitioner to primarily focus on competence-building "hands-on" activities and formative feedback provision. Even though previous studies had also suggested this connection (e.g., Sureka et al., 2013; Davies et al., 2013) this work provided an explicit and transparent analysis of the specific types of learning activities employed in each group throughout the action research to support the statement.

Based on these empirical results, the key insights which can be elicited include:

- The FCM is appropriate for maximizing classroom time invested on collaborative, hands-on activities. Therefore, it can be exploited to promote engaging approaches to K-12 ICT teaching and learning (e.g., problem- and project- based approaches). Considering the reported benefits of such learning approaches to effectively promote core student skills and digital competences, such as creative coding and computational thinking (Sharples et al., 2015), this promising potential of FCM should be further examined. Furthermore, the evidence related to increased frequency of student-student and student-teacher interaction during classroom-based sessions further supports this claim.

- The FCM is most beneficial for improving the learning experiences of low-performing students. This provides promising evidence for addressing a significant issue in K-12 ICT teaching, namely the commonly reported gender gap (Wang et al., 2015). It has been globally acknowledged that girls tend to have lower performance and engagement (or attitudes) towards ICT during K-12 Education, leading to a smaller percentage of female ICT professionals. In this context, the reported benefits of FCM could be further investigated in terms of addressing this global challenge.

Although our study provides evidence on students' motivation, engagement and learning outcomes, there are also some limitations. First, the generalizability of the results must be carefully approached since the study was conducted within a specific context (e.g., educational level, course). Second, self-report methods (surveys and teacher journal) were used to measure the motivation and engagement variables, so some of the results might have a common method biases. However, the main focus of our study was to evaluate the FCM in K-12 ICT teaching through a more holistic lens, namely students' motivation, engagement and cognitive learning outcomes. This reduces the common method bias as we used both attitudinal and cognitive variables. Nevertheless, additional research is needed to complement our findings based on deeper qualitative methods, such as in-depth interviews, interaction analyses and behavioral patterns.

Future work should include further research for explicitly evaluating other aspects of the potential of FCM towards enhancing students' learning experiences in ICT (Giannakos et al., 2016), such as the impact on the affective status of students, the potential for addressing the widely acknowledged gender gap on performance and motivation towards ICT, as well as the capacity to foster creative computational thinking skills. Furthermore, more longitudinal approaches should de designed, so as to gain insights on the impact of the FCM on students' learning experiences over a wider span of school time (more than one school year). Such longitudinal studies should also aim to capture, process and report additional qualitative evidence on how FCM can affect the learning process and students' development of digital citizenship skills including computational thinking, collaboration skills and potentially minimizing the globally acknowledged gender gap. Finally, future work should also take into account the state-of-the-art in the emerging fields of Teaching and Learning Analytics (Sergis & Sampson, 2016; Sergis & Sampson, In Press). These fields investigate tools and methods to support teachers engage in evidence-based reflective re-design of their teaching practice based on the analysis of student educational data. The added-value of these emerging technologies is that they may also exploit the collection and processing of student data which can transcend action-based data and may include more fine-grained student characteristics, such as their emotions. Thus, they can offer a much richer evidence pool, which teachers can process and exploit when investigating and (re)designing their practice to enhance the provision of personalized learning experiences to their students.

References

Altrichter, H., Feldman, A., Posch, P., & Somekh, B. (2008). *Teachers investigate their work: An Introduction to action research across the professions* (2nd ed.). New York, NY: Routledge.

Amresh, A., Carberry, A. R., & Femiani, J. (2013). Evaluating the effectiveness of flipped classrooms for teaching CS1. In *Proceedings of the 2013 IEEE Frontiers in Education Conference* (pp. 733-735). doi:10.1109/FIE.2013.6684923

Baepler, P., Walker, J. D., & Driessen, M. (2014). It's not about seat time: Blending, flipping, and efficiency in active learning classrooms. *Computers & Education*, *78*, 227-236.

Balanskat, A., & Engelhardt, K. (2015). *Computing our future computer programming and coding-priorities, school curricula and initiatives across Europe*. Brussels, Belgium: European Schoolnet. Retrieved from http://tinyurl.com/zagj3wj

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. Washington, DC: International Society for Technology in Education.

Bishop, J. L., & Verleger, M. A. (2013). The Flipped classroom: A Survey of the research. In *Proceedings of the 120th ASEE National Conference* (Vol. 30, pp. 1-18). Atlanta, GA: ASEE.

Chen, Y., Wang, Y., Kinshuk, & Chen, N. S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers & Education, 79*, 16-27.

Choi, E. M. (2013). Applying inverted classroom to software engineering education. *International Journal of e-Education, e-Business, e-Management and e-Learning, 3*(2), 121-125.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education* (6th ed.). New York, NY: Routledge.

Commonwealth of Australia. (2010). *Information and Communication Technology (ICT) competence*. Retrieved from http://tinyurl.com/ho8khwv

Davies, R. S., Dean, D. L., & Ball, N. (2013). Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. *Educational Technology Research and Development, 61*(4), 563-580.

Day, J. A., & Foley, J. D. (2006). Evaluating a web lecture intervention in a human–computer interaction course. *IEEE Transactions on Education, 49*(4), 420-431.

DeLozier, S. J., & Rhodes, M. G. (2016). Flipped classrooms: A Review of key ideas and recommendations for practice. *Educational Psychology Review*, 1-11.

Di Serio, A., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers & Education, 68*, 586-596.

Dolgopolovas, V., Savulionienė, L., & Dagienė, V. (2014). Enhancing students' motivation in the inverted CS2 course: A Case study. In *Proceedings of the International Conference on e-Learning 2014* (pp. 137-141). Tenerife, Spain: Education, Audiovisual and Culture Executive Agency.

Eurydice. (2012). *Developing key competences at school in Europe: Challenges and opportunities for policy*. Luxembourg: Publications Office of the European Union. doi:10.2797/93204

Fryling, M., Yoder, R., & Breimer, E. (2015). Full flip, half flip and no flip: Evaluation of flipping an introductory programming course. In *Proceedings of the Conference on Information Systems and Computing Education* (pp. 1-14). New York, NY: ISCAP.

Gannod, G. C., Burge, J. E., & Helmick, M. T. (2008). Using the inverted classroom to teach software engineering. In *Proceedings of the 30th international conference on Software engineering* (pp. 777-786). New York, NY: ACM.

Gehringer, E. F., & Peddycord III, B. W. (2013). The Inverted-lecture model: A Case study in computer architecture. In *Proceedings of the 44th ACM technical symposium on Computer science education* (pp. 489-494). New York, NY: ACM.

Giannakos, M. N., Krogstie, J., & Aalberg, T. (2016). Toward a learning ecosystem to support flipped classroom: A Conceptual framework and early results. In Y. Li, M. Chang, M. Kravcik, E. Popescu, R. Huang, Kinshuk, & N.-S. Chen, (Eds.), *State-of-the-Art and Future Directions of Smart Learning* (pp. 105-114). Singapore: Springer.

Giannakos, M. N., Krogstie, J., & Chrisochoides, N. (2014). Reviewing the flipped classroom research: Reflections for computer science education. In *Proceedings of the Computer Science Education Research Conference* (pp. 23-29). New York, NY: ACM.

Hayashi, Y., Fukamachi, K. I., & Komatsugawa, H. (2014). Evaluation of a flipped classroom & analysis of students' learning situation in a computer-programming course. *Information Modelling and Knowledge Bases XXVI, 272*, 120-127.

Herold, M. J., Lynch, T. D., Ramnath, R., & Ramanathan, J. (2012). Student and instructor experiences in the inverted classroom. In *Proceedings of the 2012 IEEE Frontiers in Education Conference* (pp. 1-6). doi:10.1109/FIE.2012.6462428

Horton, D., Craig, M., Campbell, J., Gries, P., & Zingaro, D. (2014). Comparing outcomes in inverted and traditional CS1. In *Proceedings of the 2014 conference on Innovation & Technology in Computer Science* Education (pp. 261-266). New York, NY: ACM.

Hung, H. T. (2015). Flipping the classroom for English language learners to foster active learning. *Computer Assisted Language Learning, 28*(1), 81-96.

Jonsson, H. (2015). Using flipped classroom, peer discussion, and just-in-time teaching to increase learning in a programming course. In *Proceedings of the 2015 IEEE Frontiers in Education Conference* (pp. 1-9). doi:10.1109/FIE.2015.7344221

Keller, J. M. (Ed.) (2010). *Motivational design for learning and performance: The ARCS model approach*. Tallahassee, FL: Springer.

Kong, S. C. (2014). Developing information literacy and critical thinking skills through domain knowledge learning in digital classrooms: An Experience of practicing flipped classroom strategy. *Computers & Education, 78*, 160-173.

Lewin, K. (1948). *Resolving social conflicts; selected papers on group dynamics.* New York, NY: Harper & Row.

Love, B., Hodge, A., Grandgenett, N., & Swift, A. W. (2014). Student learning and perceptions in a flipped linear algebra course. *International Journal of Mathematical Education in Science and Technology, 45*(3), 317-324.

Mason, G. S., Shuman, T. R., & Cook, K. E. (2013). Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course. *IEEE Transactions on Education, 56*(4), 430-435.

OECD. (2014). *Measuring the digital economy: A New perspective*. doi:10.1787/9789264221796-en

Phillips, D., & Carr, K. (2010). *Becoming a teacher through action research: Process, context, and self-study*. New York, NY: Routledge.

Rahman, A. A., Aris, B., Mohamed, H., & Mohd Zaid, N. (2014). The Influences of flipped classroom: A Meta-analysis. In *Proceedings of the 6th IEEE Conference on Engineering Education* (pp. 24 - 28). Kuala Lumpur, Malaysia: IEEE.

Reza, S., & Baig, M. I. (2015). A Study of inverted classroom pedagogy in computer science teaching. *International Journal of Research Studies in Educational Technology, 4*(2), 19-30.

Sharples, M., Adams, A., Alozie, N, Ferguson, R., Fitzgerald, E., Gaved, M., McAndrew, P., Means, B. Remold, J. Rienties, B., Roschelle, J. Vogt, K. Whitelock, D., & Yarnall, L. (2015). *Innovating pedagogy 2015: Open University innovation report*. Milton Keynes, UK: The Open University. Retrieved from http://oro.open.ac.uk/45319/1/InnovatingPedagogy_2015.pdf

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for information, 22*(2), 63-75

Sergis, S., & Sampson, D. (2016). Towards a teaching analytics tool for supporting reflective educational (re)design in inquiry-based STEM education. In *Proceedings of the 16th IEEE International Conference on Advanced Learning Technologies.* doi:10.1109/ICALT.2016.134

Sergis, S., & Sampson, D. (In Press). Teaching and Learning Analytics to support Teacher Inquiry: A Systematic Literature Review. In P. Peña-Ayala (Ed.), *Learning analytics: Fundaments, applications, and trends: A view of the current state of the art*, Heidelberg: Springer.

Sureka, A., Gupta, M., Sarkar, D., & Chaudhary, V. (2013). *A Case-study on teaching undergraduate-level software engineering course using inverted-classroom, large-group, real-client and studio-based instruction model.* Retrieved from http://tinyurl.com/gnmghvo

Tahir, N. M., Othman, K. A., & Yahaya, F. H. (2011). Case study of jigsaw cooperative learning effect within Electrical Engineering courses. In *Proceedings of the 2011 IEEE Conference on Business, Engineering and Industrial Applications* (pp. 20-23). Kuala Lumpur, Malaysia: IEEE.

Tanner, M., & Scott, E. (2015). A Flipped classroom approach to teaching systems analysis, design and implementation. *Journal of Information Technology Education: Research, 14,* 219-241.

Tsai, C. W., Shen, P. D., & Lin, R. A. (2015). Exploring the effects of student-centered project-based learning with initiation on students' computing skills: A Quasi-experimental study of digital storytelling. *International Journal of Information and Communication Technology Education, 11*(1), 27-43.

US Department of Education. (2010). *Partnership for 21st century skills*. Retrieved from http://www.p21.org/

Wang, J., Hong, H., Ravitz, J., & Ivory, M. (2015). Gender differences in factors influencing pursuit of computer science and related fields. In *Proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education* (pp. 117-122). New York, NY: ACM.

Wang, H. Y., Huang, I., & Hwang, G. J. (2016). Comparison of the effects of project-based computer programming activities between mathematics-gifted students and average students. *Journal of Computers in Education, 3*(1), 33-45.