Reviewing the Flipped Classroom Research: Reflections for Computer Science Education

Michail Giannakos
John Krogstie
Nikos Chrisochoides
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Michail N. Giannakos and John Krogstie
Norwegian University of Science and Technology (NTNU), Trondheim, Norway
and
Nikos Chrisochoides
Old Dominion University, VA, USA

Recent technical and infrastructural developments posit flipped (or inverted) classroom approaches ripe for exploration. Flipped classroom approaches have students use technology to access the lecture and other instructional resources outside the classroom in order to engage them in active learning during in-class time. Scholars and educators have reported a variety of outcomes of a flipped approach to instruction; however, the lack of a summary from these empirical studies prevents stakeholders from having a clear view of the benefits and challenges of this style of instruction. The purpose of this article is to provide a review of the flipped classroom approach in order to summarize the findings, to guide future studies, and to reflect the major achievements in the area of Computer Science (CS) education. 32 peer-reviewed articles were collected from a systematic literature search and analyzed based on a categorization of their main elements. The results of this survey show the direction of flipped classroom research during recent years and summarize the benefits and challenges of adopting a flipped approach in the classroom. Suggestions for future research include: describing in-detail the flipped approach; performing controlled experiments; and triangulating data from diverse sources. These future research efforts will reveal which aspects of a flipped classroom work better and under which circumstances and student groups. The findings will ultimately allow us to form best practices and a unified framework for guiding/assisting educators who want to adopt this teaching style.

Categories and Subject Descriptors: K.3.2 [Computer and Information Science Education]: Computer Science Education.
H.5.3 [Group and Organization Interfaces]: Collaborative computing, Computer-supported cooperative work, Evaluation/methodology

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1. INTRODUCTION

Traditional lecture style is the most common teaching approach used in higher education classes; however, the traditional lecture style of teaching can often place students in a passive role, which typically involves students retaining isolated facts that can later be forgotten. Over the last few decades, instructors have moved away from the traditional lecture approach by increasing technology use as a way to extend and enhance students’ understanding. One strategy recently adopted by many stakeholders is the flipped (or inverted) classroom approach: students use technology to access the lecture and other instructional resources outside the classroom, leaving the in-class time to engage in active learning through problem-based learning and practice activities [Giannakos and Chrisochoides, 2014; Bishop and Verleger, 2013].

The flipped classroom is a specific type of blended learning design that restructures the traditional lesson [Lage et al. 2000]. Recent developments in open education and video lectures have given rise to flipped classrooms. Since this specific type of blended-learning classroom can utilize technology, such as video and other forms of multimedia, to move lectures outside the classroom, students and teachers have time for active learning in the classroom [Bishop and Verleger 2013]. The flipped classroom has been used in a number of education studies [Bishop and Verleger 2013], particularly in higher education, with very encouraging results [Gannod et al. 2008; Mason et al. 2014].

Our motivation for this work is based on the emerging developments in the area of video and learning technologies, creating momentum for the adoption of the flipped approach in CS education. The purpose of this paper is to provide a review of research on the flipped classroom approach in order to summarize the findings, guide future studies, and reflect the major achievements in the area of CS education. This study can provide a springboard for other scholars and practitioners,
especially in the area of CS education, to examine flipped classroom approaches by taking into consideration the prior and ongoing research efforts.

2. BACKGROUND

The flipped (or inverted) classroom approach was coined in 2000 [Lage et al. 2000], though relevant research in the area remained limited until the last couple of years. It can be argued that the key factor that increased stakeholders’ interest and postulated the flipped classroom approach as one of the main buzzwords of academic circles was recent developments in open education and technologies. To date, advanced video repository systems have seen enormous growth (e.g., Khan Academy, iTunes U), with social software tools increasing the possibilities to enhance learning material. Most of the communication software tools, including wikis, weblogs, and e-portfolios, can potentially provide a vehicle to promote the flipped classroom approach. In addition, the widespread adoption of many different video learning platforms from all the prominent universities around the world posit this hybrid teaching method ripe for exploration and increase stakeholders’ interest.

In 2000, Lage et al. talked about creating an inverted classroom for accommodating many different student learning styles. Afterwards, many other researchers have used the flipped classroom model using different technologies and pedagogical strategies [Bishop and Verleger 2013]. In the last few years, a substantial body of research has been conducted and published. In some studies, we have seen very positive results where the learning performance increases and students’ attitudes and adoption of this instruction model are high [Davis et al. 2013; Stone 2012]; however, we have also seen that students disliked video lectures and claimed that recorded lectures are not appropriate for more difficult course material [Strayer, 2012; Gannod et al. 2008]. Overall, several studies have been conducted, resulting in many useful findings, primarily in the area of CS education. Therefore, with this paper we attempt to provide a review of the flipped classroom approach in order to summarize the findings, guide future studies, and reflect the major achievements in the area of CS education.

The current review is unique since it reviews the flipped classroom style through the lens of CS education, analyzes over 30 peer-reviewed articles, offers systematic analysis of both benefits and drawbacks, and provides opportunities to improve future research.

3. METHODOLOGY

3.1 Article Collection

Several procedures were followed to ensure high quality review of the literature of flipped classroom approaches. A comprehensive search of peer-reviewed articles was conducted through June 2014. (short papers, posters, and reports were excluded), based on a wide range of key terms including: Flip the classroom, flipped class, flipping, inverting, reversing, inverted classroom, and derivatives of these terms. A wide variety of databases and meta-databases were searched, including the ACM Digital Library, IEEE Xplore, AACE Digital Library, Academic Search Premiere, EBSCOhost, ERIC, Google Scholar, and Scholars Portal Journals. Additionally, the reference section of each article found was searched in order to find additional articles. This process was conducted independently by two experts, a CS educ. researcher and a research librarian. After this process, the two researchers present their results and discussed and solved any discrepancies. The search process uncovered 32 peer-reviewed articles (Table 1).

3.2 Analysis

Each collected study was analyzed based on the following elements: educational level of the sample, subject area, methodology type (qualitative, quantitative, mixed), measure type (e.g., Attitudinal, Learning Performance, Attendance), instruments used (e.g., Surveys, Tests, Interviews), sample size, technology used, experiment design (e.g., between groups, within groups), and whether the students’ worked collaboratively or not.

4. RESULTS OF THE REVIEW

One can claim that the research on Flipped-Inverted Classroom Research has been growing in recent years. Based on our analysis, we can verify this assumption, as we can see from Table 1 that the number of papers published during the last three years has increased significantly, especially compared to the few and scattered papers before 2012. In this section, Table 1 presents the detailed results, followed by an analysis and discussion of the categories. In addition, Figures 2 and 3 present respectively the benefits and drawbacks of flipped classroom approaches, as they arose from the reviewed articles.

4.1 Sample

The categories related to the sample of the articles, include the number of students participating in each study (size) and their educational level (i.e., undergraduate, graduate). The majority of the studies involve undergraduate students (26), with few studies at the graduate level (2) and at a mixed graduate and undergraduate course (3). Regarding the sample size (figure 1), most of the studies (21) have been conducted with less than 100 students, and few (6) can be considered large scale studies (more than 200 students).
## Table 1. Published Studies of the Flipped Classroom

<table>
<thead>
<tr>
<th>Study</th>
<th>Educ. Level</th>
<th>Subject Area</th>
<th>Method. Type</th>
<th>Measure Type</th>
<th>Instruments</th>
<th>Sample Size</th>
<th>Tech. Used</th>
<th>Exp. Design</th>
<th>Collab. Learning</th>
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<td>Stone 2012</td>
<td>UG</td>
<td>Bio</td>
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<td>Per, Atti, Per</td>
<td>SR, OEQ, LPT</td>
<td>800UG-2013 GR</td>
<td>VL, AR</td>
<td>BT</td>
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<tr>
<td>Gehring and Pedycoyrd 2013</td>
<td>Mixed</td>
<td>Comp. Archit.</td>
<td>Mixed</td>
<td>Per, Acti</td>
<td>SR, LPT, OBS</td>
<td>8UG-44 GR</td>
<td>VL</td>
<td>BT</td>
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<td>Sarawagi, 2014</td>
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<td>Mixed</td>
<td>Atti</td>
<td>SR, OBS</td>
<td>26</td>
<td>VL</td>
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<td>Yes</td>
</tr>
<tr>
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<td>ENG</td>
<td>Quant</td>
<td>Atti</td>
<td>SR</td>
<td>89</td>
<td>VL</td>
<td>Non</td>
<td>No</td>
</tr>
<tr>
<td>Pierce and Fox 2012</td>
<td>Mixed</td>
<td>Medicine</td>
<td>Quant</td>
<td>Per, Atti</td>
<td>SR, LPT</td>
<td>71</td>
<td>VL</td>
<td>BT &amp; WT</td>
<td>No</td>
</tr>
<tr>
<td>Davies et al. 2013</td>
<td>UG</td>
<td>ICT</td>
<td>Quant</td>
<td>Per, Atti</td>
<td>SR, LPT</td>
<td>301</td>
<td>VL, Simul</td>
<td>BT &amp; WT</td>
<td>No</td>
</tr>
<tr>
<td>Bates and Galloway 2012</td>
<td>UG</td>
<td>Physics</td>
<td>Mixed</td>
<td>Atti, Atti, Per</td>
<td>SR, LPT, OEQ</td>
<td>200</td>
<td>AR</td>
<td>VT</td>
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<tr>
<td>Yumamoto Larson and Murphree 2014</td>
<td>Mixed</td>
<td>Digital ENG</td>
<td>Mixed</td>
<td>Atti</td>
<td>SR, FG, OBS</td>
<td>30</td>
<td>Simul</td>
<td>VT</td>
<td>No</td>
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<td>Forsey 2013</td>
<td>UG</td>
<td>Statistics</td>
<td>Mixed</td>
<td>Atti</td>
<td>FN, INT, SR, FG</td>
<td>50</td>
<td>ITS</td>
<td>VT</td>
<td>No</td>
</tr>
<tr>
<td>Lockwood and Esseltine 2013</td>
<td>UG</td>
<td>Progr. &amp; PS</td>
<td>Mixed</td>
<td>Per, Atti</td>
<td>SR, OEQ</td>
<td>35</td>
<td>AR, VL</td>
<td>Non</td>
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<td>Mason et al. 2013</td>
<td>UG</td>
<td>ENG</td>
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<td>SR, LPT</td>
<td>20</td>
<td>VL</td>
<td>BT</td>
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</tr>
<tr>
<td>Herold et al. 2012</td>
<td>Mixed</td>
<td>Soft, ENG</td>
<td>Mixed</td>
<td>Per</td>
<td>SR, INT, LPT</td>
<td>106</td>
<td>VL</td>
<td>BT</td>
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</tr>
<tr>
<td>Thomas 2014</td>
<td>UG</td>
<td>Progr.</td>
<td>Mixed</td>
<td>Atti</td>
<td>SR</td>
<td>-</td>
<td>VL, Simul</td>
<td>Non</td>
<td>No</td>
</tr>
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<td>McCray 2000</td>
<td>UG</td>
<td>IS</td>
<td>Quant</td>
<td>Atti</td>
<td>SR</td>
<td>50</td>
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<td>BT</td>
<td>No</td>
</tr>
<tr>
<td>Gannod et al. 2008</td>
<td>UG</td>
<td>Soft, ENG</td>
<td>Quant</td>
<td>Atti, Per</td>
<td>-</td>
<td>80</td>
<td>VL</td>
<td>VT</td>
<td>Yes</td>
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<tr>
<td>Enfield 2013</td>
<td>UG</td>
<td>Web Design</td>
<td>Quant</td>
<td>Atti, Per</td>
<td>SR, OEQ</td>
<td>50</td>
<td>VL, Non</td>
<td>VT</td>
<td>Yes</td>
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<tr>
<td>Szafir and Mutlu, 2013</td>
<td>UG</td>
<td>Web Design</td>
<td>Quant</td>
<td>Per, Atti, BM</td>
<td>EEG, SR, LPT</td>
<td>48</td>
<td>VL</td>
<td>BT</td>
<td>No</td>
</tr>
<tr>
<td>Campbell et al. 2013</td>
<td>UG</td>
<td>CS1</td>
<td>Quant</td>
<td>Atti, Per, Atti</td>
<td>SR, LPT</td>
<td>351</td>
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<tr>
<td>Foertsch et al. 2002</td>
<td>UG</td>
<td>PS, CS</td>
<td>Mixed</td>
<td>Atti, Per</td>
<td>LPT, OEQ, INT</td>
<td>531</td>
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<tr>
<td>Largent 2013</td>
<td>UG</td>
<td>CS0</td>
<td>Mixed</td>
<td>Atti, Per</td>
<td>SR, OEQ</td>
<td>49</td>
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<td>BT</td>
<td>Yes</td>
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<tr>
<td>Day and Foley 2006</td>
<td>UG</td>
<td>HCI</td>
<td>Quant</td>
<td>Atti, Per</td>
<td>LPT, SR</td>
<td>46</td>
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<td>VT</td>
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<tr>
<td>Wilson, 2013</td>
<td>UG</td>
<td>Statistics</td>
<td>Quant</td>
<td>Atti, Per</td>
<td>LPT, OEQ, INT</td>
<td>-</td>
<td>-</td>
<td>VT</td>
<td>Yes</td>
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<tr>
<td>Ferrer and O'Connor 2013</td>
<td>GR</td>
<td>Medicine</td>
<td>Quant</td>
<td>Per, Skills</td>
<td>LPT, SR</td>
<td>399</td>
<td>-</td>
<td>VT</td>
<td>Yes</td>
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<tr>
<td>Gaughan 2014</td>
<td>UG</td>
<td>History</td>
<td>Mixed</td>
<td>Per, Atti</td>
<td>LPT, SR</td>
<td>55</td>
<td>VL</td>
<td>VT</td>
<td>Yes</td>
</tr>
<tr>
<td>Love et al. 2014</td>
<td>UG</td>
<td>Math</td>
<td>Mixed</td>
<td>Per, Atti</td>
<td>SR, LPT</td>
<td>60</td>
<td>VL</td>
<td>VT</td>
<td>Yes</td>
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<tr>
<td>Lage et al. 2000</td>
<td>UG</td>
<td>CS0</td>
<td>Mixed</td>
<td>Per, Atti</td>
<td>SR, OEQ</td>
<td>189</td>
<td>VL</td>
<td>VT</td>
<td>Yes</td>
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<tr>
<td>McGivney and Xue 2013</td>
<td>UG</td>
<td>Math</td>
<td>Mixed</td>
<td>Per, Atti</td>
<td>LPT, FG, SR</td>
<td>55</td>
<td>VL</td>
<td>VT</td>
<td>Yes</td>
</tr>
<tr>
<td>Forsey et al. 2013</td>
<td>-</td>
<td>Sociology</td>
<td>Mixed</td>
<td>Atti</td>
<td>SR, FG, INT</td>
<td>80</td>
<td>VL</td>
<td>VT</td>
<td>Yes</td>
</tr>
<tr>
<td>Murphree 2014</td>
<td>UG</td>
<td>History</td>
<td>Mixed</td>
<td>Per, Atti</td>
<td>SR, LPT</td>
<td>213</td>
<td>-</td>
<td>VT</td>
<td>No</td>
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<tr>
<td>Larson and Yamamoto 2013</td>
<td>UG</td>
<td>TF</td>
<td>Mixed</td>
<td>Per, Atti</td>
<td>LPT, SR</td>
<td>125</td>
<td>VL</td>
<td>VT</td>
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<tr>
<td>Talbert 2013</td>
<td>UG</td>
<td>Math</td>
<td>Mixed</td>
<td>Atti</td>
<td>SR</td>
<td>53</td>
<td>VL</td>
<td>VT</td>
<td>Yes</td>
</tr>
</tbody>
</table>

UG, Undergraduate; GR, Graduate; ENG, Engineering; PS, Problem Solving; Atti, Attendance; Atti, Attitudes; Per, Learning Performance; BM, Biometrics; SR, Surveys; OEQ, Open Ended Questions; LPT, Learning Performance Tests, OBS, Observations, INT, Interviews; FG, Focus Groups; FN, Field Notes; VL, Video Lectures; AR, Animated Readings; BT, Between Group; VT, Within Group;
4.2 Subject area

With respect to subject area, it is clear that CS/IT subjects are dominant in flipped-learning research, with nearly half of the collected studies (15) conducted in CS/IT subject area. Research has also been conducted in subjects such as Mathematics (4), history (2), and medicine (2). Specifically in the CS/IT subjects, many studies (7) have been focused on introductory courses like IT, ICT, CS0, CS1, problem solving, and introductory programming. Nevertheless, studies have also been conducted in less generic subjects like HCI, Software Engineering, IS, Web Design, and Digital Engineering.

4.3 Type of research

One of the most important aspects in educational research is the type of methodology. By “type of methodology” we refer to the distinction among quantitative, qualitative, and mixed research. In addition to the type of methodology, our categorization used the type of experimental design, referring to the distinction among the following experimental designs: within-groups, between-groups, non-design, and a combination of within-between research designs. In a within-groups (or between-subjects) design, a subject is observed only one time, followed by a comparison between the control and experimental groups. In a within-groups (or subjects) design, a subject is observed at the beginning and end of the treatment; then a pre-post comparison follows. Based on this categorization, we can see from Table 2 that the majority of the papers are quantitative (15) and mixed (14,) with few studies (2) being totally qualitative. Regarding the type of experimental design, most of the studies followed a between-groups design (13) and fewer within-groups design (8). Many of the studies (9) did not follow any of these designs, but simply measured the results after the respective treatment. A very small number of studies (2) combined between and within group designs.

4.4 Technology Used to Flip and Measures Used

Concerning the technology used, most of the studies used video lectures (25); some studies also used animated readings (4) and simulations (3); many times animated readings and simulations were used on the top pf the video lectures. Only one study used more complex Intelligent Tutoring System (ITS) technology. Regarding the measure used on the studies, most of the studies used attitudinal (27) and learning performance (19) measures (table 3). On top of the aforementioned measures, some studies also captured students’ attendance (4), skills (1) and biometrical data using EEG (1). In order to be able to capture this information, researchers used different instruments and many times a combination of them. In particular, 29 studies used surveys, 18 performance tests, 8 open ended questions, 4 interviews, 4 data from focus groups, 3 studies used observations and one study used EEG (table 3).

4.5 Summary of benefits

Figure 2 (next page) provides a summary of six key benefits regarding the use of the flipped classroom teaching approach. First, as most of the studies investigating students’ learning performance mentioned, flipping the class is a way to improve learning performance. Students particularly welcomed the fact that they had access to materials like video lectures, and they were able to prepare themselves and even learn when, where, and at the pace they wanted; students welcomed their ability to learn independently. Second, more than half the studies analyzed suggest that students have very positive attitudes toward the flip classroom approach, describing the approach as useful, helpful, and flexible. Third, a number of papers indicated high levels of engagement. Based mostly on qualitative data and instructors’ observations, it is stated that even if the performance is sometimes low, student engagement remains at a high level. Fourth, it is found that there is a measurable increase in the quantity of discussions, although the quality of discussions was not assessed in the collected studies. Fifth, flipped classrooms force students to work collaboratively, and qualitative evidences indicate that students
improved their cooperative skills. Finally, a number of articles indicated that learning habits change as a result of this approach and the availability of the extra learning materials, especially when those materials were revisited prior to a revision or examination.

### Benefits

- Increases Learning Performance
- Positive Attitudes
- Increases Engagement
- More Discussions (Qualitatively Measured)
- Enforces Cooperative Learning
- Better learning habits

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#### 4.6 Summary of challenges

Figure 3 provides a summary of three key challenges regarding the use of flipped classroom teaching approach. First, most of the studies mention the high initial cost in terms of preparation time and for the development of the inverted materials; however, this is reduced after the first year of a flipped class since the instructor is better prepared and some of the materials can be reused. Second, students sometimes struggled with the new format and were occasionally unreceptive to follow the structure; however, most of the time they adapted quickly and ultimately found the inverted classroom format to be satisfactory and effective. Finally, a number of articles indicated that by using the flipped classroom approach you might encounter a decrease in attendance, especially in large courses.

### Challenges

- High initial cost and very time consuming for the instructor
- Students unreceptive with the Structure
- Decrease of Attendance

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#### 4.7 Summary of flipped classroom research

This paper reviews the status of flipped class research of the last years and shows that:

- The number of papers has significantly increased during the last years;
- The focus of the recent studies is on empirical quantitative and mixed studies;
- There is a lack of focus on qualitative oriented studies;
- There is a high emphasis on CS/IT domains with particular focus on introductory courses like introductory programming and problem solving courses (e.g., CS0, CS1);
- Researchers focused on students’ attitudes and learning performance; and
- There are certain benefits and challenges of using a flipped class approach in your course (figures 2 and 3).

## 5. DISCUSSION AND CONCLUSIONS

After reviewing over 30 studies on flipped classroom approach, we can agree on the offered affordances and the positive effects on students’ performance, attitudes, and engagement. Flipped learning can provide the students opportunities to learn in a more differentiated manner traditional than linear and passive forms [Willey and Gardner 2013]. Students have mentioned that they appreciate the ability to digest the content in a self-paced manner, so long as it was done before the next class period. Though the majority of students completed the required prerequisite tasks on a fairly regular basis, there was consistently a small portion that did not [Davies et al. 2013; Gaughan 2014; Murphree 2014].

In terms of student engagement, flipped learning received the most positive remarks from students in the qualitative surveys (open ended questions). Students perceived the use of classroom activities that activated higher-order thinking to be more engaging [Davies et al. 2013; Wilson 2013]. Additionally, the environment afforded students to remain at higher levels of Bloom’s Taxonomy for longer periods of time [Enfield 2013]. The longer students remain in the higher levels of thinking and problem solving, the more they feel engaged with authentic learning, and the perceived quality of the learning is greater [Wilson 2013].

Flipped learning empowered students through more active learning [Lage et al., 2000]. Rather than having the instructor’s interpretation of the material delivered explicitly during class time where students passively take notes and possibly ask questions, the students were held more accountable for the front-loading of content. This more active role is difficult for some students to adjust to [Bormann 2014], but it was evident that the flipped method was successful overall, especially looking at the percentage of students who prefer a flipped environment to a traditional one [Enfield 2013].

Furthermore, the studies reviewed provide a wide variety of methods for flipping the class. Some studies used quizzes outside the classroom [Enfield, 2013; Mason et al. 2013; Strayer 2009] while others used quizzes inside the classroom [Papadopoulos, 2010]. Some studies emphasized the importance of these quizzes to students and counted them for low-stakes grading [Bormann 2014], while others simply provided them as a resource to the students with no grading benefit [Gaughan 2014].

The current review suggests that, while there are some challenges for students and instructors, there are also a number of benefits. More importantly, there are also opportunities for improving instruction that might not be feasible for traditional teaching approaches. In particular,
students’ learning performance is often observed to increase and others to stay on the same level (compared to traditional instructing approaches); students’ engagement, group-work, and critical thinking have clearly benefited from flipping the classroom. On the other hand, there are challenges, such as the instructors’ claim that they spend significantly more time preparing to flip the class and that students sometimes seem unresponsive to this teaching style and their attendance decreased.

6. FUTURE DIRECTIONS FOR THE FLIPPED CLASSROOM

A number of suggestions for further research have emerged from reviewing prior and ongoing work on flipping the classroom. One recommendation for future researchers is to clearly describe the flipped classroom approach by providing detailed information for the materials used, as well as the pedagogical strategies, especially in subjects like IT/CS where technology sometimes has both the role of the content and the medium. This will allow us to identify which aspects, technologies, and concepts of the flipped classroom work better than others and to form best practices, providing a springboard for other scholars. Another recommendation is to focus more on the in-class part of the flipped classroom approach; limited research has been conducted on how instructors can motivate and engage students in active participation and critical discussions, as well as how technology can assist in that direction. Future work should also focus on collecting and triangulating different types of data from different sources. Although the reviewed studies have been conducted using a wide range of collected data, ranging from students’ attitudes and learning performance to even biometric characteristics, the interpretations and triangulation between the different types of the collected data were limited. For example, issues referring to any potential effect of students’ attitudes on their learning performance or attendance have not yet been explored. In-depth qualitative investigation on low performers and adopters is also yet to be conducted. These future research efforts will allow us to understand which aspects of flipping the classroom work better and under which circumstances and students.

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