Exploring Students Perceptions and Performance in Flipped Classroom Designed with Adaptive Learning Techniques: A Study in Distributed Systems Courses

Pedro T. Araújo[1], Windson C. Viana[1], Nécio L. Veras[1], Eder J.P. Farias[1], Jose Aires C. Filho[1]

[1]Universidade Federal do Ceará (UFC) - Fortaleza, CE – Brazil

Abstract. *In Computer Science, teaching Distributed Systems presents many challenges primarily related to the students' prior knowledge. Some new Learning Approaches emerged and can aid to improve learning processes in this scenario, such as Flipped Classroom and Adaptive Learning. In this context, this paper presents a study of the integration of the Flipped Classroom method with Adaptive Learning techniques for assisting Distributed Systems courses. We conducted quantitative and qualitative analysis to evaluate students' acceptance. We also implemented a quasi-experimental study to evaluate the learning impact on students. Students had a significant improvement in the test score in both approaches.*

1. Introduction

With the Internet era, Distributed Systems (DS) became widespread. They are a complex field of study in Computer Science and foundation of current technology paradigms such as Cloud Computing and Internet of Things [Hundt et al. 2017]. Teaching DS requires students practical and theoretical knowledge. For understanding them, students must be familiar with precedent concepts often taught in other courses, such as Operating Systems, Web Programming, and Computer Networks.

Flipped Classroom is a promising teaching method. It recommends students to come to the class after completing significant preparatory work (available typically online). The learning content delivery happens before the class (contrasting with traditional approaches), and practical activities are held collaboratively in the classroom (e.g., project design, software programming, classroom discussions) [Bergmann and Sams 2012]. Flipped Classroom approach can have its advantages mitigated when the quality of the out-class instructional material is low, since it influences students' engagement directly [Maher et al. 2015]. Also, frequently, students receive a single generalised material targeting all students in the course. Adaptive Learning techniques are a good method to improve the learning instructional material, by personalising it according to the students' needs and skills [Van Seters et al. 2012]. In our vision, students should access to a preparatory material adapted according to their learning profile and previous knowledge. In the literature, we found some related work integrating Flipped Classroom with Adaptive Learning in Mathematics [Chi et al. 2017] and Chemical Engineering [Kakosimos 2015]. However, none studies are combining these two approaches to teach Distributed Systems.

We presented the first ideas to teach Distributed Systems (DS) through the use of the Flipped Classroom Method (FCM) in [Araujo et al. 2018]. In this paper, we go fur-

DOI: 10.5753/cbie.sbie.2019.219

ther, by surveying 20 DS professors and by implementing a quasi-experiment with DS students. Therefore, this paper describes an approach to teach Distributed Systems through the use of the Flipped Classroom Method (FCM) supported by Google Suite technologies (i.e., Google Docs and Google Forms). We also extend it with Adaptive Learning techniques for adapting the out-of-class instructional content manually. We applied FCM in three Distributed Systems courses at two educational institutions; two of them had both undergraduate and graduate students. Our model of FCM is composed of an online out-of-class instructional material (e.g., Youtube videos, podcast, papers and quizzes) and in-class activities, such as the use of a network simulator, group discussion, and collaborative software programming. We also introduced an adaptation guide to help students in navigating in the instructional content by using online self-assessment quizzes. In this paper, our focus is the evaluation of FCM in a specific topic of the course: the Blockchain technology. We evaluated the student's acceptance of FCM and its learning impact. For the last evaluation, we carried out a study following a pretest-posttest design.

The remainder of this paper presents our research methodology and discusses the assessment and the results.

2. Methodology

This study is an intervention of a quantity-qualitative nature. We divided our research into four stages. The first step was to investigate the scenario of DS courses in universities. In this stage, we made bibliographical studies and applied an online survey with 20 professors from distinct universities of three countries. The second stage consisted of the creation of the Blockchain Flipped Classroom with adaptation techniques. The third step was to apply it in three classes to validate the students' acceptance, and, finally, in the fourth stage, we carry out a learning impact assessment.

2.1. DS professors survey

We created an online form that was sent to several professors of Computer Science in Brazil, France, and USA. We obtained 20 answers from professors of distributed systems. 13 of the 20 professors have never used active learning methodologies in their DS courses. However, most of them (55%) do practical activities in the classroom (e.g., programming classes). 75% of them pointed out students have moderate difficulty in understanding DS content. However, the same professors indicate that part of the students has problems with previous concepts from other courses. This situation requires the application of review classes (e.g., Computer Network, Operation Systems). The percentage of 65% of the professors also agree that students have difficulties with the chained content of the DS course, i.e., classes that are given at the beginning of the course (e.g., consensus algorithms), which are not well understood, will make difficult to learn of concepts at the ending of the course (e.g., Blockchain Proof of Work method). We claim FCM with Adaptation techniques is propitious to assist the student in minimising the two problems mentioned above: concepts of precedent courses and topics from DS course itself without boring those students that already have this knowledge. In this paper, our focus is to describe the use of this approach in the Blockchain class. We chose this topic because of its current importance and its complexity.

2.2. Flipped Classroom Model

Figure 1 shows the FCM adopted in this research. Professors of the course prepare the out-of-class instructional content with materials to be explored by students and online quizzes to guide students' flow of study (I). Students follow the instructions and conduct their study using self-assessment quizzes (II). When the class starts, professors give a quick review of the topics covered by the out-of-class material and answer questions students may have (III). Practical activities are also carried out, i.e., students use simulators, discuss problems presented, and do a coding exercise (IV).

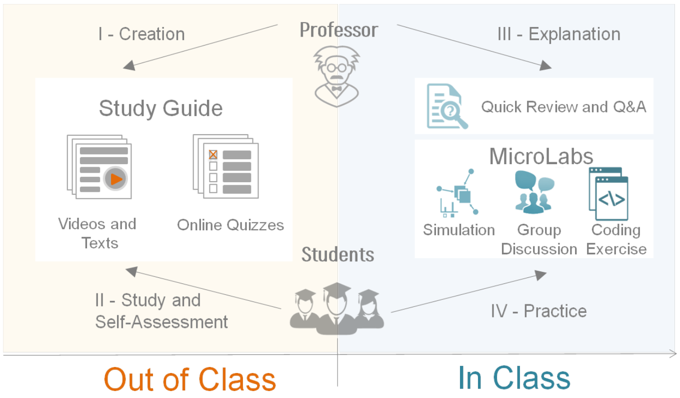

Figure 1. Our Flipped Classroom Model for DS courses

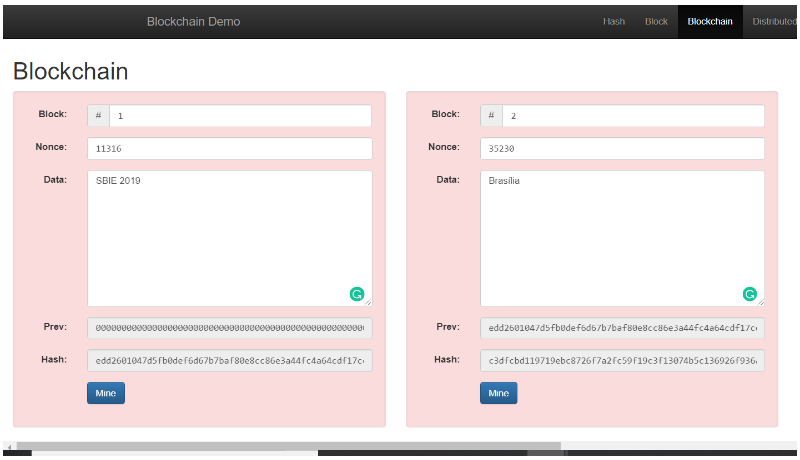

Figure 2. Blockchain Simulation

The out-of-class content is structured as study guides[1]. They follow the structure proposed by the author of [Maher et al. 2015], which integrates the use of video libraries, online surveys for self-assessment, quizzes, chapters of books, academic papers, and free web articles. We developed the Blockchain study guide using Google Docs and made it available to the students by the University Academic System. As this content (Blockchain) is very recent and requires students to have a large amount of previous knowledge for the correct understanding of this subject, this study guide was developed

[1]Study guides used in our Flipped Classrooms are available (in the Portuguese language) at https://goo.gl/Ju2D5a

using Adaptive Learning concepts. It had self-assessment questionnaires, which must be answered by the students at the beginning of the out-of-class instructional material. The primary objective of the self-assessment questionnaires was to guide the out-of-class study to be carried out by each student. After getting feedback on their current weakness, students could give importance to subjects that deserved more attention and go to study them.

We designed in-class activities using Problem-Based Learning (PBL) [Kilroy 2004] and the concept of Microlabs [Kurtz et al. 2012]. Microlabs approach, adopted by [Kurtz et al. 2012]. Figure 2 shows an example of in-class activity. It's a web-based Blockchain simulator [2] we used during the class of Distributed System.

2.3. Adaptive Learning in the out-of-class study guide

In this research, we provide adaptation of the out-of-class instructional material following three techniques: (a) selection of distinct instructional materials to explain the same topic, (b) customised students learning paths, and (c) self-evaluation quizzes. In the study guide, students can use the most suitable material according to their preferences (e.g., Podcasts or Videos about the same topic). The study guide used to teach Blockchain had several "sub-guides", which could be explored by students variably according to their learning goals and prior knowledge. The study guide [3] has 09 self-evaluation quizzes, 69 videos, 48 texts, and 43 papers. Figure 3 illustrates a relationship that each "sub-guide" had with others and aids in visualisation of possible learning paths. This figure shows Blockchain concepts and their prerequisites, following the precedence arrow. It is also possible to perceive concepts that can be learned in parallel to each other, depending on learning preferences, e.g., criptocurrencies and smart contracts. Self-assessment tests (in fact, online Google Forms) had the objective of providing a way to the student to understand his weaknesses by answering some short questionnaire before starts to study and getting some feedback about it.

A first quiz was made available to students at the start of the study guide. Learner uses this quiz to get a first perception of the general contents to be studied and where to find them among the other parts of out-of-class material (e.g., P1=Hash function, P2=Byzantine generals, P3=Asymmetric cryptography, and P4=Peer-to-peer systems). When entering a study "sub-guide", students could answer another quiz if they want to. After answering it, they could determine the amount of content that still needs to be exploited in that sub-guide or, if necessary, see all or nothing of the content. For instance, if the student knows the basic of Javascript, then he passes directly to the study of the Blockchain Javascript library without read the Javascript study guide. It is worth mentioning that the quantity of materials present in the Blockchain out-of-class material is much higher compared to other classes. This fact happens due to the characteristic of the adaptive study, where several learning paths need to be available for the learners.

[2] https://anders.com/blockchain/blockchain.html

[3] Study guides used in our Flipped Classrooms are available (in the Portuguese language) at https://goo.gl/Ju2D5a

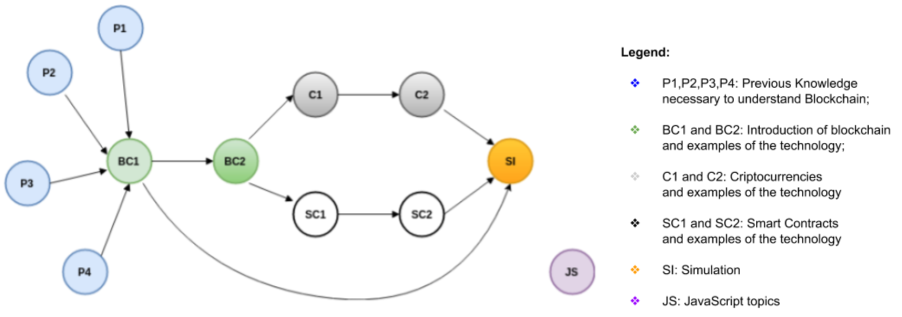

Figure 3. Adaptive Learning Flows in Blockchain class [Araujo et al. 2018]

3. The Case Study

3.1. Context and Subjects

The present study was applied during three sessions in two federal institutions of higher education, described at Table 1. The participants of the study were undergraduate students of Systems and Digital Media, Computer Science, and Computer Engineering. One session also had graduate students in Computer Science. Sessions S1 and S2 were taught during the first semester of 2018, while session S3 took place during the second semester of the same year. The sessions S1 and S3 have only undergraduate students, while the S2 was a mixed course (undergraduate and graduate students). Our study has three research questions (RQ): (RQ1) Have FCM with Adaptation Learning techniques better acceptance by students? (RQ2) Does the out-of-class instructional content improve students' learning about Blockchain? (RQ3) Are there significant differences of the student's learning impact between out-of-class instructional material with adaptation techniques and the material without them?

Table 1. Study Context

Session	Level	Students	Assessment method
S1	Undergraduate	05	Online survey
S2	Undergraduate Graduate	07 15	Online survey and Semi-structured interview
S3	Undergraduate	36	Online survey and Pretest-Posttest

3.2. FCM acceptance

In each session, students received the Blockchain study guide one week in advance to complete their home study (out-of-class). Then, they followed the instructional material and conducted their study individually. In-class, students worked on proposed problems related to the subjects studied, and they were encouraged to do so in a collaborative way (i.e., Simulation activity and Javascript programming activity). At the end of class, they delivered these activities to be corrected by the professors. Flipped Classroom evaluation forms were also made available, and students were encouraged to respond them.

3.2.1. Methods

To evaluate the overall Flipped Classrooms (out-of-class and in-class activities), we carried out an online survey (made on Google Forms) and semi-structured interviews with the DS students. We applied the online form at the end of all the three sessions. It uses the Likert scale [Likert 1932] for each question. The study conducted by [Zappe and Leicht 2009] inspired some of them. The semi-structured interviews occurred at one week after the session S2, and eight students joined this evaluation. Its primary goal was to gather information about the study guides presented to students regarding, mainly, the Adaptive Learning techniques. We also collected insights related to learning paths and how study guides could help out-class activities.

3.2.2. Results

FCM acceptance evaluation aimed to gather information about the following perspectives: (i) structure of the out-of-class instructional content, (ii) execution of proposed in-class activities, and (iii) motivation of students regarding FCM. All 63 students showed positive acceptance concerning the reading of the instructional material. More than 80% of learners answered that they agreed, totally or partially, with the statements "The structure of out-of-class instructional content guided me in the reading and navigation of the content" and "the topic division was clear". Concerning the relation between in-class activities and out-of-class material, students felt satisfied with discussions and content. Over 80% of them disagreed, partially or strongly, with the statement "In-class discussions and activities were not related with the content studied at home". Figure 4 B shows students' answers for two aspects (Q4 and Q5). For analysing them, we split the 63 students answers into two categories: A and B. The category A has 26 students from session S3 who received a study guide without adaptation. The category B has 37 students from sessions S1, S2, and S3 that received a study guide with adaptation techniques. Q4 measures the students' motivation to have other FCM courses. Q5 investigates whether students viewed the study guide entirely, given the quality of available video content. In both categories, students felt motivated and want to have more similar flipped classes (77% and 89%). Regarding Q5, 86% of category B' students and 65% of A were satisfied with available videos in the study. Regarding the research question RQ1, in both questions Q4 and Q5, the results reveal that students that received an out-of-class material with adaptation presented more interest in FCM and accepted better the study guide.

The online form has also three questions concerning the adaptation techniques: (Q1) use of self-assessment quizzes to understand their weaknesses, (Q2) use of quizzes to guide learning paths and (Q3) how difficult were the quizzes. Figure 4 A shows answers collected from 37 students of all three sessions that received the study guide with adaptation techniques. Students disagree about quizzes' difficult (Q3). However, concerning the quizzes' usage for guiding learning path choice, most of them agree on their crucial role. Their outcome maybe is from the heterogeneous classes with undergraduate and grad students. However, their challenge is also salutary to indicate where each student needs to study more at home to participate appropriately in-class activities.

The eight students that participated in the interview answered questions about

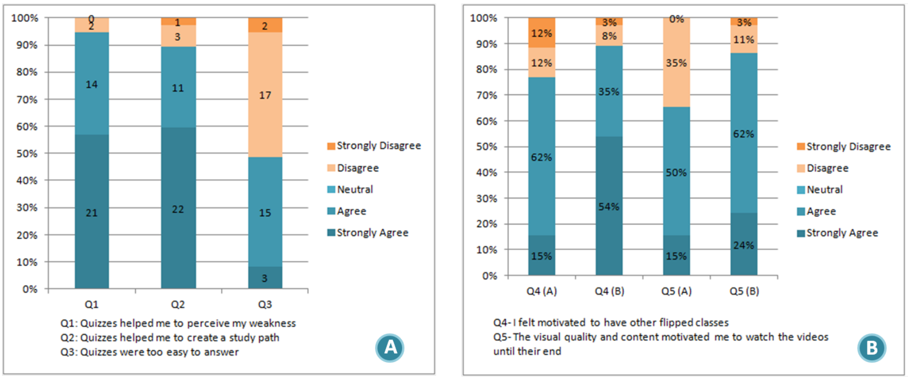

Figure 4. FCM Acceptance

adaptation techniques used in the Blockchain study guide. Questions were related to content types, the available learning paths, and the self-assessment moments. Initially, regarding materials used, answers showed that students agreed that the media presented in the out-of-class document were adequate and sufficient for the study. Some of them stated that they also sought information from other sources, but the kind of media they found matched with those of the guide. Regarding Learning Paths, students interviewed answered if they would prefer to create their learning paths (as they did in our Flipped Classroom) or receive a personalised path tailored by an instructor. Only one student replied that he preferred to receive an instructor's path, all others stated that they preferred to create study paths independently. When asked about the role of self-assessment quizzes in conducting their adaptation, all students stated that quizzes were a tool used to support their choices, and made suggestions, such as providing instant feedback on where to study content from questions that they responded incorrectly.

3.3. Assessment of Learning Impact

3.3.1. Experiment Methods and Procedure

The experiment goal was to measure the learning impact of the out-of-class material. We used the pretest/posttest[Morris 2008] method to quantitatively analyse the learning impact of session S3 students. The pretest and posttest had the same ten multiple choice questions concerning the Blockchain content (e.g., Bitcoin, Proof of Work, Hash).

Only 20 of 36 students answered both pretest and posttest. We divided them into two groups composed of 10 people (groups FC and FCWA). The groups FC and FCWA are subgroups of A and B, since we not applied the pretest and posttest to all 63 students. To decide how to split them, we conducted a pretest two week before the class. We then separated the groups randomly trying to obtain two groups with a quite similar mean score. The group FCWA received a study guide with Adaptive Learning techniques (i.e., learning paths guide, and self-assessment quizzes). The other group, FC, received a similar instructional material without self-assessment quizzes and the learning paths guide. On the day of the class, after the 10 minutes of quick review, the students of both groups answered a posttest, containing the same questions of the pretest. In resume, both groups received the students' preparatory work on the same date, they had the same time to explore the material, and they answered the same knowledge tests, either before and during class. Students who missed the pretest (16 people) received the study guide without adaptation, and we are not considering them in this experiment.

3.3.2. Results

Figure 5 shows the results of pretest (PreT) and posttest (PosT) for both groups. For answer research question RQ2, we analysed the students of both groups FC and FCWA as a single group (n=20), since both used a flipped classroom study guide. Then, we compared the pre and posttest scores (the last two Boxplots of the Figure 5). This kind of quasi-experiment is named One-Group Pretest-Posttest Design. Our students had a mean of 3.5 out of 10 in the pretest and 7.5 in the posttest. We examine if these differences are statistically significant. Since both groups are dependent, we use a Paired T-Student test. As the test needs normalised data, we applied the Shapiro-Wilk test, which confirmed the normality (0.93 with p=0.05). Our **Null hypothesis** (H_0) was: $\mu_{PoT} <= \mu_{PrT}$, that is, the posttest score (μ_{PoT}) *is not* significantly *greater than* of the pretest score (μ_{PrT}). With the test results (p-value= 7.39248e-8, $\alpha < 0.05$), H0 was rejected with *t* equals 8.067682. It means both out-class material and the way we structured the Blockchain Flipped Classroom assist in the students' learning gain significantly.

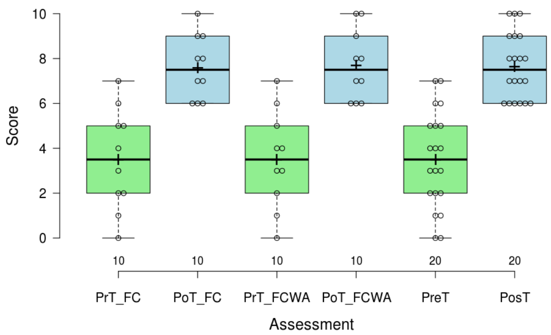

Figure 5. Students' Performance

For answer research question RQ3, we compared the pre and posttest scores of both groups (a quasi-experiment following a Two Group Pretest-Posttest design). The students of group FC had a mean of 3.5 ($SD = 2.156$) in the pretest and 7.6 ($SD = 1.356$) in the posttest with a mean gain of 4.1 ($SD = 2.165$). The students of group FCWA had similar scores, i.e., a mean of 3.5 ($SD = 2.061$) in the pretest and 7.7 ($SD = 1.486$) in the posttest with a mean gain of 4.2 ($SD = 2.31$). An Unpaired T-Student test confirms the differences among the groups are not statistically significant for $p < 0.05$ (t-value=-0.14907, p-value=0.883155, two-tailed).

4. Discussion and Threats to Validity

The results of the 63 evaluated students indicate a positive acceptance of our FCM in DS courses, especially, when students take benefits from adaptation techniques in the study guide. The way out-of-class instructional content is built favoured learning about Blockchain significantly. Our study confirms the quality of the out-of-class instructional material is an essential factor for both students' acceptance and performance as stated in [Maher et al. 2015]. According to answers collected, the study guide with adaptation techniques had better approval by students of three sessions. Then, we answered the research questions (RQ1) and (RQ2) positively. Students increased their pretest scores, after studying the out-of-class instructional content. Also, students exposed to Adaptive Learning techniques showed more acceptance when compared with other students.About the research question RQ3, the pretest-posttest quasi-experiment shows that the use of instructional material with adaptation techniques does not significantly impair students' learning comparing with a study guide without adaptation. On the one hand, the adapted study guide requires answering quizzes (i.e., students do extra work). On the other hand, students could choose to access less content when they outperformed these tests (e.g., a student S had an excellent performance in Javascript test, and decide not to read the Javascript content). Our concern was that an adaptive approach could prejudice some students in cases where the tests did not adequately assess their knowledge. Fortunately, that was not what happened in our experiment. The results show that it is possible to adapt the out-of-class content (or provide ways to adjust it manually) and to continue maintaining a suitable learning performance.

In fact, the group of students who receive a study guide with adaptation techniques does not present a learning gain statically different from the learning gain of the students who received the complete study guide. But, both groups improve this gain significantly. In short, the FCM approach made positive effects on learning of Blockchain concepts. Students were more prepared for in-class discussions and activities. Interviews and answers to forms also confirm the students' acceptance of this type of approach.

Some factors may have caused bias in our study. For instance, Blockchain is a hot topic, and its complexity requires substantial prior knowledge in Computer Science to understand the concepts thoroughly. This thematic fits perfectly in the context in which adaptive learning is better accepted (i.e., various student profiles concerning prior knowledge and multiple ways to learn). Also, as a "hot topic", students are more motivated to study Blockchain content and search other material beyond those given to them in the study guide. We did not measure this phenomenon in our research. Regarding the learning impact assessment, both pretest and posttest had the same ten questions. In this case, a threat to validity is that student may have studied having those questions in mind or talked with other colleagues. These situations turn easier answering the posttest one week after. Although, they were not aware of the posttest until the day we applied it.

5. Conclusion and Future Work

This work presented the use of Flipped Classrooms combined with Adaptive Learning techniques for the teaching of Distributed Systems topics. Results show that students received the proposed teaching strategy positively. They confirmed the desire to have other similar classes, and their acceptance of FCM was positive for most of them. Some challenges arose during the process of teaching with Flipped Classrooms supported by Adaptive Learning. For example, the difficulty to create the instructional content. The out-of-class material considered prerequisites and some learning paths that students can follow (during their study at home). To choose the videos, write the quizzes, and design the learning path guide cost us a considerable preparation time. Regarding students, difficulties can arise with factors like "time" and "maturity". Harmonising the activities from other courses with traditional teaching methodologies and the FCM's out-of-class activities are challenging for them. So, in some classes, students may arrive without read the out-of-class material entirely. In the case of our study, they had to deliver before the class a five open-questions activity, which "obligated" them in a certain way to read the material before the class.

As future work, we intend to collect data of professors regarding their perceptions of Flipped Classrooms with Adaptive Learning techniques. The primary purpose is to understand the requirements and limitations of the development of a tool to be used to support FCM in DS courses. This tool will be designed to facilitate the development of instructional materials (out-of-class instructional content and students' preparatory work) with Adaptive Learning techniques.

References

Araujo, P., Viana, W., Veras, N., and de Castro Filho, J. A. (2018). Aprendizagem adaptativa em aulas invertidas de sistemas distribuídos: um estudo de caso apoiado no g suite. In *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE)*, volume 29, page 328.

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

Chi, Y. L., Chen, T. Y., and Hung, C. (2017). Learning adaptivity in support of flipped learning: An ontological problem-solving approach. *ChemElectroChem*, (April 2015):1–14.

Hundt, C., Schlarb, M., and Schmidt, B. (2017). SAUCE: A web application for interactive teaching and learning of parallel programming. *Journal of Parallel and Distributed Computing*, 105:163–173.

Kakosimos, K. (2015). Example of a micro-adaptive instruction methodology for the improvement of flipped-classrooms and adaptive-learning based on advanced blended-learning tools. *Education for chemical engineers*, 12:1–11.

Kilroy, D. (2004). Problem based learning. *Emergency medicine journal*, 21(4):411–413.

Kurtz, B. L., Fenwick Jr, J. B., and Meznar, P. (2012). Developing microlabs using google web toolkit. In *Proceedings of the 43rd ACM technical symposium on Computer Science Education*, pages 607–612. ACM.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of psychology*.

Maher, M. L., Latulipe, C., Lipford, H., and Rorrer, A. (2015). Flipped classroom strategies for cs education. In *Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, SIGCSE '15, pages 218–223, New York, NY, USA. ACM.

Morris, S. B. (2008). Estimating effect sizes from pretest-posttest-control group designs. *Organizational Research Methods*, 11(2):364–386.

Van Seters, J., Ossevoort, M., Tramper, J., and Goedhart, M. J. (2012). The influence of student characteristics on the use of adaptive e-learning material. *Computers & Education*, 58(3):942–952.

Zappe, S. and Leicht, R. (2009). Ac 2009-92:"flipping" the classroom to explore active learning in a large undergraduate course. *age*, 14:1.