Automatic Personalisation of Study Guides in Flipped Classroom: A Case Study in a Distributed Systems Course

Pedro Araújo, Cecília Costa, Windson Viana
Federal University of Ceará
Fortaleza, Brazil
pedrotaraujo@gmail.com
cecilia@great.ufc.br
windson@virtual.ufc.br

Nécio de Lima Veras
Federal Institute of Ceará
Tianguá-CE, Brazil
necio.veras@ifce.edu.br

Eder J.P. Farias
State University of Vale do Acaraú
Sobral-CE, Brazil
eder_porfirio@uvanet.br

***Abstract*—In Computer Science programs, teaching the subject of Distributed Systems (DS) presents many challenges, especially 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. Using these approaches together enables students to explore content in a personalised way while meeting the professor-defined course objectives. In this context, our work presents a study of the integration of Flipped Classes with Adaptive Learning techniques for supporting the learning of Distributed Systems. We developed a tool to assist in the creation and generation of personalised study guides. To evaluate it, we conducted a Case Study mixing quantitative and qualitative analysis with 26 students during an entire semester of a DS course. The results indicate most students positively evaluated our approach and felt motivated in following new flipped classes with personalised study guides.**

***Index Terms*—Adaptive learning, Flipped Classroom, Computer Science Education, Distributed Systems**

I. Introduction

The study and application of Distributed Systems(DS) concepts are becoming more and more present in Computer Science programs. This presence occurs either directly, in a specific DS course, or indirectly, in topics that make use of Distributed Systems concepts [1], like Internet of Things or Cloud Computing. Teaching Distributed Systems courses is challenging because the concepts taught are not elementary, and the students' background is very heterogeneous when they start following the course [1] [2]. DS professors teach new software development approaches (e.g., REST communication, event-based systems) and students must be familiar with topics taught previously for understanding those lectures. Students need to have a good background from courses like Web Developing and Computer Networks.

Active learning is generally defined as any instructional method that engages students in the learning process. It requires students to do meaningful learning activities and think about what they are doing [3] [4]. In the context of Active Learning, Flipped Classroom advocates that students must have the first contact with the lesson content at home. They should read or watch videos and make an analysis of the lesson material before class time. After, they will apply these concepts in classroom activities conducted by their teachers [5]. Thus, the presentation of content occurs individually at home (contrasting with traditional approaches), and practical exercises (e.g., simulations, programming micro-projects) are held collaboratively during class time. This type of class changes the role of professors from the leading player of learning to the mediator of students' learning [6]. Flipped classroom model can also be integrated with other approaches. Adaptive learning, for instance, offers the opportunity of personalisation of the lesson content according to students' specific needs (e.g., students' prior knowledge and their individual learning goals), rather than the professor determining the same course material for the whole class.

Flipped Classroom may have its advantages mitigated when the quality of the material produced to study at home is low since it directly influences students' engagement [7]. Professors complain that part of the students don't follow the guidelines completely and may arrive in class unprepared to perform the activities. Professor's skills are essential for the planning and execution of the activities in the flipped classroom. However, not all professors have support teams to build multimedia content exclusive to their courses. They often mix their production with reused texts, videos, and slides available on the Web. With that material, they create "Study Guides (SGs)" with links to this content, i.e., a professor acts as a curator of the material to be studied before class.

In our research, we combine Adaptive Learning and Flipped Classroom approaches aiming to offer the personalisation of SGs used in flipped classes. We designed a web-tool called FCTool (Flipped Classroom Tool), which helps professors to produce SGs as a Document Product Line [8]. Professors describe the variability of SGs and the rules to adapt them according to the students' specific needs. With FCTool, professors create SGs (e.g., list of videos, research papers, podcasts) with obligatory and optional content. They annotate

Identify applicable funding agency here. If none, delete this.

the SG variabilities with rules related to quiz evaluations. In the next phase, the students read the study instructions and answer the quizzes. With responses of the student, FCTool adapts the SG for him. It offers more or less lesson content to the student according to the professor's specification. In the classroom, students are, then, involved in practices related to the content under study. To gather evidence that corroborates our beliefs, we conducted a case study on a Distributed System course during an entire semester. The class had 26 students, 5 from an undergraduate program and 21 from a master and doctorate program. We had five flipped classes, and in three of them we use FCTool to generate personalised SGs. We aimed at answering the following research questions: **(RQ1)** Is it practical to use variability models to represent and generate personalised study guides (SGs)? **(RQ2)** Do the personalised study guides (SGs) improve students'learning? **(RQ3)** Are there significant differences in the student's learning impact between personalised study guides (SGs) and the material without them?

We organised the remainder of this paper as follows. In Section II, we describe the research methodology followed in this study. Section III presents FCTool and its design principles. Section IV describes the DS course in which we implemented the case study. Section V exhibits the main results of our units of analysis. Section VI presents the overall discussion concerning our approach. Section VII concludes the paper and shows some threats to its validity.

II. Research Methodology

Inspired on the results of the paper [9], in 2017, we started to adopt Flipped Classroom methodology in our Computer Networks and Distributed System courses. For example, in Computer Networks (two classes of 30 students), 25% of the lessons were flipped throughout the year. Student feedback was very positive, especially in the first classes. In the case of the Distributed Systems course, however, we noticed students had more difficulty due to the heterogeneity of student profiles. At our university, this course mixes undergraduate and graduate students. In 2018, we decided to start research in the teaching of Distributed Systems [10]. Fig 1 illustrates its timeline. The first idea was to provide a more comprehensive study guide with a visual guide so that the student could decide which part of the lesson content he should follow. It has worked as a process of "SG personalisation", but the students by themselves who adapted the study guide [2]. In parallel, we began to investigate whether the challenges we were facing in DS courses were recurrent in other universities. Then, we decided to conduct an online survey with DS professors. From this perspective, we started the design and development of FCTool. In 2019, we started our case study, reported in this paper, in which three of the five inverted classes used the tool to generate personalised SGs. Finally, we implement a qualitative assessment with two other professors of DS courses to get tool feedback and prospect new uses and features.

Our research can then be characterised as exploratory and used mixed methods of assessment (quantitative with ques-

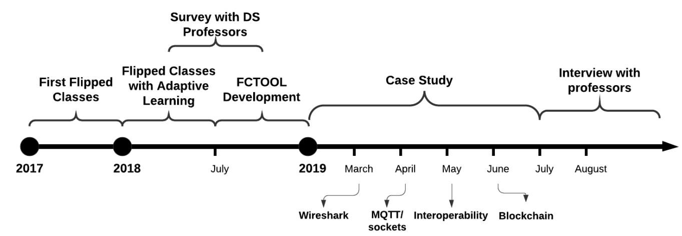

Fig. 1. Research Timeline

tionnaires and tests with students) and qualitative with DS professors. The FCTool design process followed the User-Centered Design (UCD) methodology to avoid unnecessary information and useless features on it.

A. Challenges of Distributed Systems Teaching

We created an online form that was sent to several Computer Science professors from South America, Europe, and the USA (we obtained 20 answers from distributed systems professors) [2]. We perceived some difficulties for teaching DS: (1) professors need to updated lessons regularly; (2) fundamental theoretical parts are not always easy to learn (e.g., consensus algorithms, logical clocks, concurrency control algorithms); (3) heterogeneous student groups form the class with distinct profiles concerning their previous knowledge (e.g., operation systems, programming, computer networks); (4) students desire practical lessons, particularly involving programming; and (5) students also have difficulties with "chained course topics". Lessons at the beginning of the course (e.g., consensus algorithms), if they are not well understood, will make it difficult for students to learn some topics at the ending of the course (e.g., Blockchain Proof of Work method).

B. Challenges of Flipped Classroom

We believe the use of Flipped Classroom help professors to mitigate challenges presented in last subsection since it encourages professors to develop distinct learning experiences fitting for any student, respecting their context [11]. Literature Results showed that the flipped classroom model impacted student learning positively. Although using this methodology will imply dealing with additional obstacles [12] [13] [14]. We highlight (1) professors' difficulties during material production of the SGs. They need to be motivated and confident with adequate levels of time, skills, and resources. (2) lack of specific tools for flipped classroom since, in general, professors use a set of combined tools (e.g. Kahoot, Youtube, LMS) to create and make available their SGs; (3) the choice of videos' duration time, which should not be extensive but it should cover all content; (4) frequently, students receive the same study guide independently of their specific needs; and (5) students' commitment may decrease during the course.

C. Flipped Classroom Flow

We designed FCTool to help professors in the creation of SGs that can be adapted for each student automatically in the context of Flipped Classroom. Frequently, the flow used in this kind of classes had two moments. Prior to the class, professors propose SGs (e.g., list of videos, a research paper) to students study at home. Figure 2 illustrates the steps of the flipped class adopted. Before class, the process of the flipped class begins with the production of the study guide to be sent to the students (I - Professor, Prepare). In the next phase, after receiving the study materials, the students should follow the guidelines and should read and watch the lesson content. Also, they should answer the evaluation quizzes linked in the SG. (II - Students, Study, and Self-Assessment).

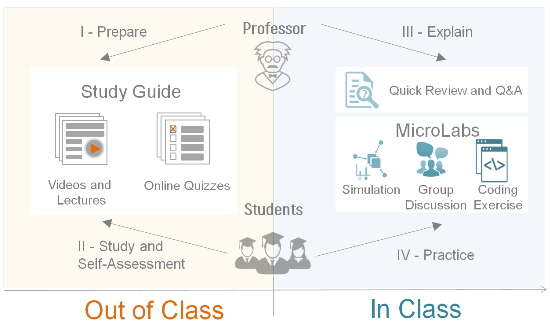

Fig. 2. Adopted Flipped Class Model

The structuring of the SGs is based on an initial model proposed in [9]. The SGs sent to students consisted of different types of materials, such as videos, content-related texts, and assessment quizzes (at the end of the study guide). In the classroom, the first moment is devoted to questions and answers about the studied contents, as well as a brief explanation of contents by the professor (III - Professor, Explain). Finally, students are involved in practices related to the lesson under study (IV - Students, Practice). The activities were designed so that they had a short duration of time. This allows students to complete and deliver their answers in the same class. Simulations, discussions, and programming activities took place collaboratively among students. [7]

III. FCTool

A. Design Principles

We elicited the desired characteristics of FCTool from our initial research in the context of Distributed Systems flipped classes [2]. We investigated students' acceptance and performance when submitted to the flipped classes with personalised SGs generated manually. We, then, identified as desirable requirements for FCTool:

1) The personalised SGs of the flipped classes should be a set of modules (i.e., sub-documents) that may or may not be included in the SGs send to students;
2) A module could be another adaptable guide;
3) The tool should allow professors to consider students' performance in questionnaires or assessment quizzes into the personalisation process. Besides, FCTool must recognise the relationship of this performance with the modules that will be inserted in the final study guide;
4) The modules should have multiple modals (e.g., video, podcast) to benefit students with distinct learning styles;
5) The tool must integrate with software already in use by professors and students;
6) The tool should allow the professor to reuse SGs or modules from precedent lessons.

B. FCTool features

As we mentioned in section II-A, we noticed that there is no specific tool for building SGs for flipped classes. In general, a variety of web tools are used to compose the study guide, create the content itself (e.g., Screencast, Powtoon) or use existing material (e.g., Youtube, Vimeo, Scientific Sites, Quiz Tools). Thus, instead of creating a single tool to concentrate all these activities, we opted for integration with *Google Gsuite* package (specifically the *webapps: Google Drive, Google Forms* and *Google Docs*). The aim was to ensure that the creation of personalised SGs was not limited by the editing functionality offered in our tool. Users will have access to all the existing functionality of *Google* products during the process of producing their SGs. We implemented the integration with G Suite using the Google App Script (GAS) language[1]. In this work, we integrated study guides documents and quiz forms in Google platform folders. In addition to the files persistence, Google email service was also used to deliver the personalised SGs.

We followed the concept of document variability model [8]. Our approach aims to offer to the professor a way to define multiple versions of a study guide, which FCTool will adapt according to the students' answers given in the self-assessment quizzes. A first part of the tool works as a markup language in which the professor uses these markups when designing a study guide template in Google Docs. Figure 4 shows an overview of the creation process. The professor can mark parts of the study guide that are mandatory, and also optional pieces. These optional parts will be evaluated by the tool against the answers students give in quizzes. The professor will also design these quizzes by using Google Forms. Then, FCTool allows associating the evaluation results of the quizzes with parts of the study guide that should or should not be included in the personalised study guide. For instance, Figure 3 shows the variability model for the Interoperability study guide. The professor can indicate students will receive a review of XML if they fail to answer at least 70% of the quizzes about XML concepts correctly. The same idea works for the YAML, JSON, Protocol Buffer modules, only the Introduction and the Final Exercises modules are mandatory for this SG.

FCTool adaptation rules provide the variability representation of a study guide. In a template document (we named Adaptable Study Guide), the professor builds common tables in the *Google* text editor, where the first line stores the tag to identify the type of function and the other lines store the parameters that will be used in the adaptation routines. The

[1]GAS is a language similar to JavaScript, which has specific customisation for *Google* applications.

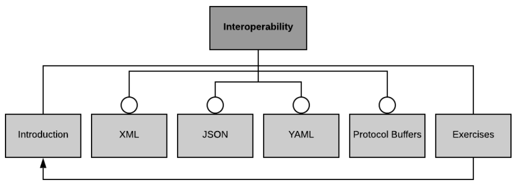

Fig. 3. Example of Adaptable Study Guide

filling of the tables with the identification and the arguments of the functions can be done manually. However, to facilitate the creation of this template, a customised menu was implemented in the *Google Doc*s toolbar. Figure 5 shows the options available in the tool menu. Figure 6 shows the workflow personalised SG generation. The professor sent to students a quiz link (e.g., through the academic system). Each student provides his answers. FCTool then use these answers to generate and send a personalised study guide for each student, automatically. They are sent via email using an automated routine implemented in FCTool.

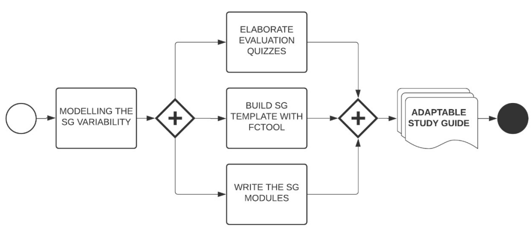

Fig. 4. Process of Adaptable Study Guide Creation

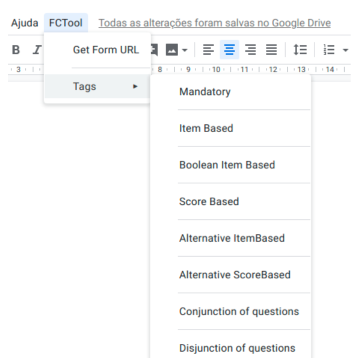

Fig. 5. FCTool Menu to Help Adaptable SG Creation.

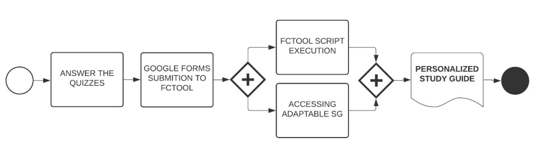

Fig. 6. Process of Personalised Study Guide Generation

IV. Case Study

Our case study aimed to collect data on how students perceive the use of Flipped Classes and Adaptive Learning in a Distributed Systems course supported by FCTool. We followed the case study methodology described by Runeson *et al.* [15]. We split the study into two units of analysis according to the research questions presented in Section I. In the first unit, we evaluated RQ1 and RQ2 during two flipped classes. In the second unit, we also conducted a quasi-experiment[2] to evaluate RQ3 during a class at the end of the course.

A. Context

Our case study took place in a DS course in a public university in 2019. The class consisted of 26 participants with various academic levels (undergraduate and graduate students). Five of them were undergraduate students of Bachelor of Systems and Digital Media and Bachelor of Computer Science, and twenty-one were graduate students (master and doctorate) of a Computer Science program. The course had two professors; one is the head of this research. The course had 64h and mixed traditional classes with five flipped classes. All classroom activities took place in a computer lab and lasted three hours and thirty minutes each. The first and second flipped classes were about Computer Networks review and Distributed System architectures. Practical classes were made with the Wireshark simulator and students presentations on known distributed systems (e.g., Netflix). In these two classes, we do not use FCTool or made any evaluation. The objective was to acclimatise students first with the flipped classroom approach. The other three flipped classes were: Interoperability, Sockets/Message Queuing Telemetry (MQTT), and Blockchain. The 26 students did not always participate fully in classes. Sometimes they did not answer the pretests or feedback evaluations. In the results of each class, we highlight each participation.

B. Materials and methods

This case study used quantitative and qualitative data. Initially, data were collected on students' perceptions regarding the use of Flipped Classrooms, as well as evaluating the use of Adaptive Learning in the study guide adaptation process. For this, we created questionnaires using the Google Suite platform.The main objective of the evaluation was to gather information about the adequacy of the SGs produced in relation to the student needs. The following criteria were evaluated: content organisation; adequacy of the contents with the previous knowledge of the students; and the contribution of the study guide in their learning. An analysis of the motivation to have other Flipped and Adaptive Lessons was also performed. The evaluation forms had questions elaborated using the Likert scale [17]. Some questions are inspired by the study [18]. The evaluation form had questions about the adequacy of the SGs provided, the lesson content, and the practical activities made in the classroom. Also, the surveys

[2] According to [16] a quasi-experiment is a type of empirical study that does not have complete control and randomness in group selection.

included questions concerning the acceptability of the overall approach. At the end of these forms, students were able to provide suggestions and comments on the personalised SGs generated and on the classroom practices.

We adopted a pretest and posttest technique to assess students' learning impact [19] in all flipped classes. The questions present in both tests were identical. Pretests also worked as input data to the study guide personalisation process. Once students received the personalised SG, they had ten days to be prepared for the classroom activities. Students answered the posttests before the classroom activities. Thus, the assessed learning impact is related to the students' study prior to the class meeting with the professor. Additionally, in unit 2, we implemented a quasi-experiment to compare student performance. We divided the class into two groups. We use the pretest results to support the group division. The participants were separated using a pseudo-randomised process according to the score obtained by the students in the pretest. So, the two groups had similar mean scores. The control group received a study guide without adaptation. FCTool sent a personalised SG to each student of the experimental group.

C. Flipped Classes

The first evaluation session took place during the flipped class of the Interoperability topic. In this class, 25 students had their personalised SGs generated by the tool. The second session took place during the lesson of Sockets and MQTT topics (a month later). For each of these contents, the students received a study guide, but the classroom activities of both themes took place on the same day. The idea was to compare direct (request-reply) to indirect communication (pub-sub). The first half of the class meeting was devoted to Socket activities and the second half to MQTT activities. Twenty-four students generated personalised SGs about Sockets topic. Twenty students received personalised SGs about MQTT. The third and last evaluation of the developed software was made in Blockchain class. Seventeen students participated, but only nine students received personalised SGs, as the class was split to conduct a quasi-experiment.

The activities proposed in our Flipped Classes were designed using Problem-Based Learning (PBL) [20] and the concept of Microlabs [21]. In Problem-Based Learning, the knowledge students already have is restructured in a more realistic context. In this type of study, students are exposed to collaborative learning, group discussions or peer education [20]. Microlabs approach, adopted by [21] advocates that activities performed in the classroom must be short (5-15 minutes) and they must occur during class meetings time.

V. Results

A. Evaluation of the personalised study guides

The analysis of the SGs aimed to gather information from the following perspectives: (1) frequency of modules addition in each study guide, (2) number of different SGs generated, and (3) possible learning trails in the SGs. In the Interoperability class, 25 students generated personalised SGs. In total, FCTool generated seven distinct study guides. The number of optional module inserts in the personalised SGs is shown in Table I. Contents of YAML and Protocol Buffers were added more frequently than other optional modules (Figure 3 shows the variability diagram for this study guide). The fact that these external representation protocols are relatively new and not yet widely used as XML and JSON may have contributed to the greater number of SGs additions. For instance, thirteen students did not receive XML content in their study guides.

TABLE I
INSERTION OF MODULES (INTEROPERABILITY)

Introduction/Exercises	XML	JSON	YAML	*Protocol Buffers*
25	12	21	23	23

Table II details the modules added to the personalised Sockets SGs. Altogether 24 students engaged in the class, using the FCTool to produce personalised SGs. The modules additions occurred with a similar frequency, between 12 and 15 times for each content.

TABLE II
INSERTION OF MODULES (SOCKETS)

TCP/UDP	Streaming	Sockets (intro)	S & T
15	12	14	13

Figure 7 shows the variability diagram for the MQTT adaptable study guide. It also indicates the number of inserts for each module. In the MQTT study guide, students self-declare their profile (e.g., I know MQTT but never programmed with it). Most students chose to receive the content provided in the first profile. In this option, the student was completely unaware of the MQTT protocol and had no knowledge related to how programming with it. Fifteen students opted to receive the IoT review module. All 22 SGs generated included the Event-Based Communication module.

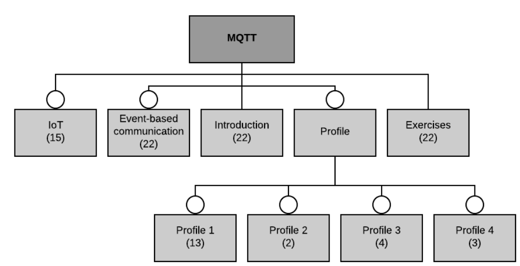

Fig. 7. MQTT Adaptable Study Guide

Blockchain SG was the most extensive SG in our study. The SG included a large amount of previous knowledge necessary for Blockchain understanding (e.g., consensus algorithm). Table III shows the number of optional module inserts in Blockchain personalised SGs. Nine participants received personalized SGs in this flipped class. All nine SGs were different. The most added modules were on the Byzantine Generals problem (Biz) and JavaScript (JS) concepts.

TABLE III
INSERTION OF MODULES (BLOCKCHAIN)

Cryptography	Hash	P2P	JS	Biz	Bchain	Coins	Contracts
2	3	1	7	6	5	2	3

B. *Student Motivation and Acceptance*

The evaluation questionnaire had twelve questions. In this section, we show the result of four of them[3].. Regarding the acceptability of the personalised SGs, students showed high acceptance. For all three flipped classes, more than 86% of the students ticked “Agree” and “Strongly Agree” for the statement *“The study guide presented fits to my current knowledge”* (P1). Figure 8 illustrates students’ responses to P1 in each class. In the Interoperability class, five (71.42%) students agree that the SG was adequate, while in the Socket/MQTT class, this number rises to 14 (82.34%). In Blockchain class, all students agreed that the personalised SG was appropriate. Based on these results, students’ acceptance increased throughout the course, probably due to a better understanding of how flipped classes work. The students’ agreement was 86.2% in all classes.

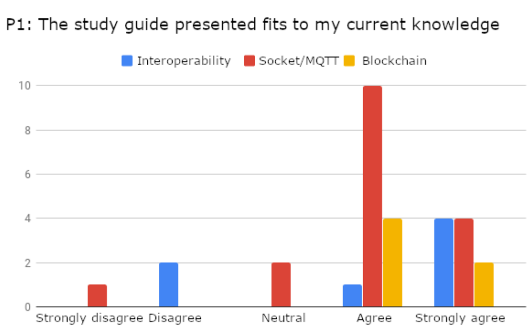

Fig. 8. Study Guide Acceptance

The P2 statement was about the assistance that the study guide provided for classroom activities. The statement was: *“I felt prepared for in-class activity when conducting my studies with my personalised study guide”* (P2). Figure 9 shows the answers provided by the students. Considering all flipped classes, we have a total of 26 among 29 answers which agree with the statement proposed in P2. This amount represents 89.65% of the responses. Thus, we can infer that the personalised study guides (most of them distinct for each student) were evaluated as satisfactory for P2. For each class, the number of students who ticked “Agree” and “Strongly Agree” was above 80% of responses provided.

Students also evaluated the content organisation of the personalised SGs. Students evaluated the validity of the statement *“The content organisation presented in the study guide was clear”* (P3). This statement was considered valid by 25 (86.2%) of the students, who agree or strongly agree with this statement. Figure 10 provides all the answers for each flipped

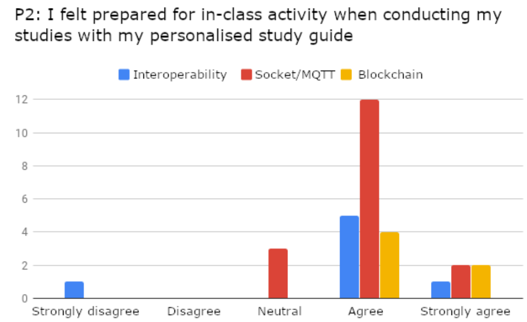

Fig. 9. Student Preparation

class. P4 statement analysed the students’ motivation concerning our approach (Figure 11). Most students (82.75 %) agree with the statement *“I felt motivated to take more activities with flipped classroom and adaptive learning techniques”*(P4).

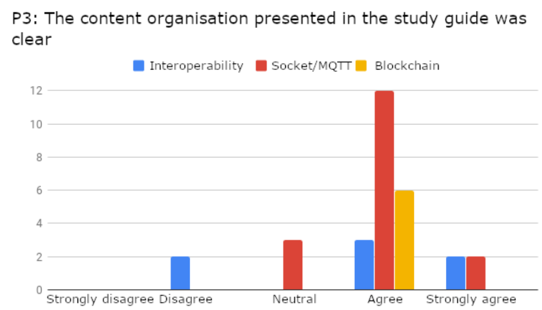

Fig. 10. Study Guide Organisation Assessment

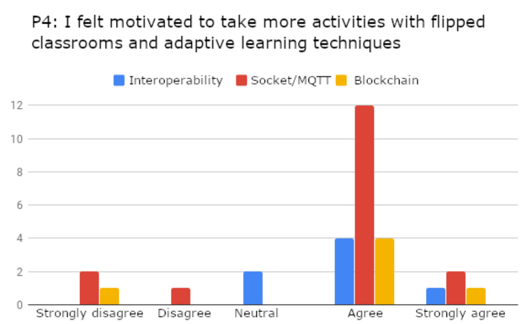

Fig. 11. Student Motivation Assessment

C. *Learning Impact in Unit 1*

Assessing “learning impact” is notoriously difficult due to external factors that can contribute to learning. Despite this difficulty, we try to measure knowledge gain that students had when following the study guides. Our goal was also to encourage students to read the material and arrive well prepared for classroom activities since they were invited to answer a posttest before each face class. In the Unit 1, we

[3] Lack of space forbade us to describe the whole procedure and its data

used a One-Group Pretest-Posttest design since there was not a control group. The pretest and posttest of the Interoperability topic had six questions whose total score was ten points (the questions present in both tests were identical). Seventeen students answered both pretest and posttest. The lowest grade obtained in the pretest was 0 and the highest was 10. In the posttest, students scored between 3 and 9. The Alpha Cronbach for this test was 0.7363016811. This indicates good reliability of internal consistency for the questionnaire, i.e the internal items are sufficiently different and measure distinct elements [22]. Figure 12 illustrates the distribution of the student scores. The gray Boxplot represents the grades obtained in the pretest and the white, the grades obtained by the students in the posttest. The mean and standard deviation, respectively, of the pre-test score was 3.58 and 2.62 and the post-test score was 7.47 and 1.77. We examine if these differences are statistically significant. Since both groups are dependent, we use a Paired T-Student test. As the test needs Normal-distributed data, we applied the Shapiro-Wilk test, which did not reject normality (p-value is 0.248 with $\alpha = 05$). 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= 0.0000101610, $\alpha < 0.05$), H0 was rejected with *t* equals 5.951020. The results indicate the personalised study guide and the way we structured the flipped class, for this topic, assists in the students' learning gain before the classroom activities significantly.

The pretest and posttest of the Sockets/MQTT class had seven questions whose total score was ten points (the questions present in both tests were identical). Twenty-two students answered both pretest and posttest. The pretest scores ranged from 0 to 10. Alpha Cronbach for this test was 0.7601851852 which an excellent reliability of internal consistency [22]. In the posttest, the scores ranged from 4.6 to 10. Figure 13 show the pretest and posttest results. The pretest scores are in gray and the posttest scores in white. The mean score obtained by the students before follow the study guide was 4.21 with standard deviation 3 and after the studies the mean was 8.84 with standard deviation 1.4. We examine if these differences are statistically significant. Since both groups are dependent, we use a Paired T-Student test. As the test needs Normal-distributed data, we applied the Shapiro-Wilk test, which did not reject normality (p-value is 0.471 with $\alpha = 05$). 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= 8.12345e-8,α < 0.05), H0 was rejected with *t* equals 7.664694. As same as for the Interoperability topic, the results were statistically significant.

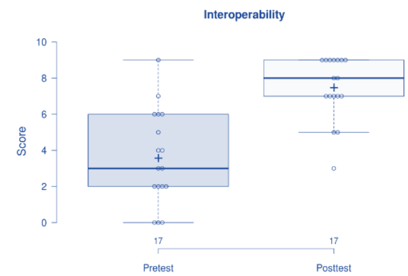

Fig. 12. Interoperability Learning Impact

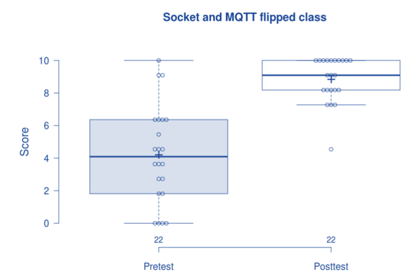

Fig. 13. Sockets/MQTT Learning Impact

D. Learning Impact in Unit 2

For Blockchain class, the students were divided into two groups. Seventeen students participated in this study. The first group, called the experimental group (EG), consisted of 9 students, who received personalised SGs generated by the FCTool tool. The second group, called control group (CG), consisted of 8 students, who received the same and complete SGs (without personalisation). **Our hypothesis** is that EG will perform similarly to CG, even though the former received less content than the latter. The pretest and posttest of both groups had eight questions whose total score was ten points (the questions present in all tests were identical). Figure 14 shows the plot of the scores obtained in the pretest and posttest in both groups. Alpha Cronbach for this test was 0.5909679992, validating a satisfactory internal consistency for the questionnaire [22].

Control group pretest scores (Pre_CG) ranged from 0 to 7, with a mean of 3.37 and standard deviation 2.5. The posttest score of the control group (Post_CG) was between 6 and 10, with a mean score of 8.62 and standard deviation 1.59. The pretest scores of the experimental group (Pre_Ep) followed the variation between 1 (lowest score) and 8 (highest grade), the mean score of this evaluation was 4 and standard deviation 2.39. In the posttest evaluation, the experimental group (Post_EG) ranged from 8 to 10, with a mean score of 9.44 and standard deviation 0.72. We can see that students' scores generally experienced a considerably increase after their home studies. The mean and standard deviation , respectively, of the pretest for all students was 3.70 and 2.39, while the mean and standard deviation of the posttest score was 9.05 and 1.24. We compared the score gain (posttest score minus the pretest score) for both groups. Students in EG obtained a mean gain of 5.44 ($SD = 2.815$). The students of CG had a mean gain of 5.25 ($SD = 2.05$). An unpaired T-Student test confirmed that these differences between the groups are not statistically significant for $p < 0.05$ ($t - value = 0.16183, p - value = 0.873603, two - tailed$).

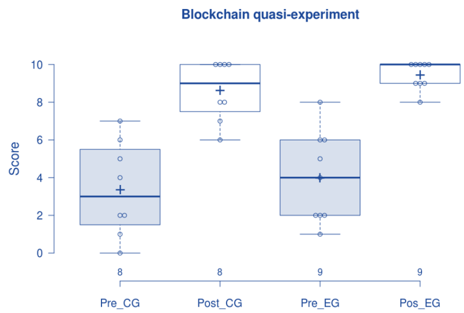

Fig. 14. Blockchain Student Performance

VI. Discussion

A. (RQ1) Is it practical to use variability models to represent and generate personalised study guides (SGs)?

We use FCTool to model four adaptable study guides using the document variability approach. Two authors of the research created the scripts in the tool for those study guides. During the case study, as described in the Results section, 35 different SGs were generated. Therefore, 50% of all SGs delivered were personalised. No bugs were reported during the personalisation process confirming FCTool practicability.

B. (RQ2) Do the personalised study guides (SGs) improve students'learning?

According to the data collected, we can infer early study before the face-to-face meeting had positive effects on the topics evaluated. For instance, in unit 1, the two professors of the DS course designed the classroom activities related to Interoperability and Socket/MQTT using pair-programming tasks. Students' performance on these activities in the classroom would be inadequate if the students did not arrive in the class day with a minimum of knowledge on these topics. We remember that it is precisely this minimum content that professors included in the study guides. Concerning the evaluation of flipped classes (study guides and face-to-face classes), students approved the approach used. Most of the answers provided demonstrated satisfaction with the SG delivered, their content organisation, SGs contribution to their learning, the quality of the practical activities in the classroom, and their motivation to have new flipped classes with the personalised study guides.

C. (RQ3) Are there significant differences in the student's learning impact between personalised study guides (SGs) and the material without them?

The results of unit 2 indicate that receiving a smaller and personalised study guide did not negatively impact the student's learning. However, we were not able to state that adaptive learning usage for the study guides implies a significant increase in learning impact.

D. What are the challenges to follow this methodology?

The way we conceive FCTool requires professors to have basic programming skills to design a study guide using document variability. In addition to the participants of the case study, we evaluated the tool with two other professors to find out if the document variability representation is viable [4]. We trained the two professors to use FCTool and produce adaptable study guides. A post-use interview was conducted with them. They stated positive feelings about the ease of use of the adaptation rules. The two approved the proposed approach and affirm they would use the tool in the Flipped Classroom context. Regarding students, difficulties can arise concerning factors like "time" and "maturity", which are required for following the study guides. Reconciling the activities of other courses that use traditional teaching methodologies with Flipped Classes activities can be challenging for students, especially those who carry out professional activities. As a countermeasure, during these two years of research, we realised that requiring students to take a test before coming to the face-to-face class increases their engagement.

VII. Final Considerations

Distributed Systems are a complex field of study in Computer Science and to teach DS is challenging. It requires some practical and theoretical knowledge from students. In this research, we presented FCTool to assist DS professor in the description and generation of flipped classes study guides. Our approach tries to personalised the student experience during the Flipped Classroom process of home study.

During our case study, students' perception was positive in most of the time during class meetings. Students collaborate a lot, and the majority of them came to the classroom well prepared to work on the proposed practical activities.

A. Threats to Validity

Some factors might cause bias in our study. As a case study, this research fits into a particular context. We did not select the DS course randomly. The head of this research was one of the professors. Another factor is the sample size of students in our tests. Only 26 took part in our study. Also, it is not an external professor that designed the adaptable study guides and used FCTool to manage them. Concerning the learning impact assessment, both pretest and posttest had the same questions. In this case, a possible threat to validity is that students might have discussed these questions or even followed the study guide with them in mind although they were not aware of having to do a posttest in a week.

B. Future work

As future work, we intend to implement more professor assessments. The main goal is to better understand the requirements and limitations of the FCTool tool and thus be able to implement improvements for later versions. Also, we are planning to use the whole approach in other courses as Software Engineering and Data Structures.

[4]Lack of space forbade us to describe the whole procedure and its data

References

[1] C. Hundt, M. Schlarb, and B. Schmidt, "SAUCE: A web application for interactive teaching and learning of parallel programming," *Journal of Parallel and Distributed Computing*, vol. 105, pp. 163–173, 2017.

[2] P. Araujo, W. Viana, N. Veras, E. J. Farias, and J. A. de Castro Filho, "Exploring students perceptions and performance in flipped classroom designed with adaptive learning techniques: A study in distributed systems courses," in *Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE)*, vol. 30, p. 219, 2019.

[3] C. C. Bonwell and J. A. Eison, *Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports.* ERIC, 1991.

[4] M. Prince, "Does active learning work? a review of the research," *Journal of engineering education*, vol. 93, no. 3, pp. 223–231, 2004.

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

[6] A. King, "From sage on the stage to guide on the side," *College teaching*, vol. 41, no. 1, pp. 30–35, 1993.

[7] L. L. Lacher and M. C. Lewis, "The effectiveness of video quizzes in a flipped class," in *Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, pp. 224–228, ACM, 2015.

[8] M. C. Penadés, J. H. Canós, M. R. Borges, and M. Llavador, "Document product lines: variability-driven document generation," in *Proceedings of the 10th ACM symposium on Document engineering*, pp. 203–206, ACM, 2010.

[9] M. L. Maher, C. Latulipe, H. Lipford, and A. Rorrer, "Flipped classroom strategies for cs education," in *Proceedings of the 46th ACM Technical Symposium on Computer Science Education*, pp. 218–223, ACM, 2015.

[10] P. Araujo, W. Viana, N. Veras, and J. A. de Castro Filho, "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)*, vol. 29, p. 328, 2018.

[11] A. G. de Oliveira Fassbinder, M. Fassbinder, and E. F. Barbosa, "From flipped classroom theory to the personalized design of learning experiences in moocs," in *2015 IEEE Frontiers in Education Conference (FIE)*, pp. 1–8, IEEE, 2015.

[12] P. Strelan, A. Osborn, and E. Palmer, "The flipped classroom: A meta-analysis of effects on student performance across disciplines and education levels," *Educational Research Review*, p. 100314, 2020.

[13] A. G. de Oliveira Fassbinder, D. Moreira, G. Cruz, and E. F. Barbosa, "Tools for the flipped classroom model: An experiment in teacher education," in *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*, pp. 1–8, IEEE, 2014.

[14] A. Amresh, A. R. Carberry, and J. Femiani, "Evaluating the effectiveness of flipped classrooms for teaching cs1," in *2013 IEEE Frontiers in Education Conference (FIE)*, pp. 733–735, IEEE, 2013.

[15] P. Runeson, M. Host, A. Rainer, and B. Regnell, *Case Study Research in Software Engineering: Guidelines and Examples*. Wiley Publishing, 1st ed., 2012.

[16] D. T. Campbell and H. Riecken, "Quasi-experimental design," *International encyclopedia of the social sciences*, vol. 5, pp. 259–263, 1968.

[17] R. Likert, "A technique for the measurement of attitudes.," *Archives of psychology*, 1932.

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

[19] D. M. Dimitrov and P. D. Rumrill Jr, "Pretest-posttest designs and measurement of change," *Work*, vol. 20, no. 2, pp. 159–165, 2003.

[20] D. Kilroy, "Problem based learning," *Emergency medicine journal*, vol. 21, no. 4, pp. 411–413, 2004.

[21] B. L. Kurtz, J. B. Fenwick Jr, and P. Meznar, "Developing microlabs using google web toolkit," in *Proceedings of the 43rd ACM technical symposium on Computer Science Education*, pp. 607–612, ACM, 2012.

[22] L. J. Cronbach, "Coefficient alpha and the internal structure of tests," *psychometrika*, vol. 16, no. 3, pp. 297–334, 1951.