An Action Research Study towards the Use of Cloud Computing Scenarios in Undergraduate Computer Science Courses

Heleno Cardoso da Silva Filho and Glauco de Figueiredo Carneiro
Universidade Salvador (UNIFACS), Salvador-BA, Brazil

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Abstract: Cloud computing has been a successful paradigm in its goal to provide remote computing resources in a competitive and scalable way when compared to traditional computing scenarios. Companies have a growing interest in migrating and using cloud services. However, the literature has reported difficulties and challenges faced by companies while migrating their assets to the cloud. One of the possible reasons for this is the difficulty in the identification of qualified professionals to support companies to plan, perform and monitor the migration of their legacy systems to the cloud. This paper presents an action-research study analyzing the inclusion of cloud computing scenarios in the System Analysis and Design and Operating Systems undergraduate courses at Salvador University (UNIFACS). The results of the action-research study provided initial evidence that cloud computing resources integrated to the contents of the aforementioned courses can contribute to motivate and engage students in activities. In addition, the knowledge and experience gained by these students can improve their qualification to facilitate access to the labor market.

1 INTRODUCTION

Cloud computing paradigm has the goal to provide services and scalable resources at an accessible cost with acceptable levels of elasticity and reliability (Armbrust et al., 2010; Zhang et al., 2010). It is an evolutionary step towards the effective use of computational resources (Oliveira et al., 2014). Moreover, it can be a solution for companies to deal with issues such as cost reduction as well as the possibility to change the configuration and the allocation of computational resources, including software and hardware, on demand (Armbrust et al., 2010; Oliveira et al., 2014).

Researchers have identified key advantages and challenges faced by practitioners. In terms of advantages, we highlight *elasticity* (Armbrust et al., 2010), *scalability* (Marston et al., 2011), *storage capacity* (Bond, 2015), *cost reduction* (Marston et al., 2011), and *mobility* (Fernando et al., 2013). In terms of potential challenges that are bound to concerns faced during Cloud Computing adoption, we mention the following (de Paula et al., 2017; Sultan, 2010): *security* [1], *reliability* (Sultan, 2010), *privacy and confidentiality* (Ryan, 2011), *portability* (Jones et al., 2017), and *interoperability* (Petcu and Vasilakos, 2014).

There is a tendency towards the use of cloud computing in several areas and this is not an exception for education (Lin et al., 2014; Smith et al., 2014). The demand for professionals to configure and manage cloud computing resources is an opportunity for new practitioners in cloud computing related activities. Despite this opportunity, there is still an open question on how undergraduate students can be prepared to deal with the cloud computing paradigm. Studies have reported the need to engage Computer Science undergraduate students in hands-on activities (Hanna et al., 2015; Vaquero, 2011). The lack of motivation affects the learning process and therefore can interfere in the execution of activities. For this reason, it is advisable to include in the courses activities that resemble real situations related to cloud issues in an attempt to engage students (Lin et al., 2014). For example, activities dealing with the identification of which cloud provider to choose, as well as a feasibility analysis related to the migration of the assets and potential services of an organization to the cloud can be interesting scenarios to grasp students attention. The challenges faced by newcomers while executing cloud activities may include the identification of which cloud provider to hire and the respective resources to allocate to a new service (Oliveira et al.,

[1] www.cloudsecurityalliance.org

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2014; Sadiku et al., 2014).

Empirical instruments are an effective option to analyze the effectiveness of the aforementioned activities. In fact, studies have reported the use of these instruments in Computer Science undergraduate courses where students can experience real-life problems that can motivate them towards positive learning outcomes (Smith et al., 2014; Vaquero, 2011; Sultan, 2010).

Considering the scenario described above, we defined the following **Research Question (RQ)**: "Analyze *the use of cloud computing scenarios* for the purpose of *understanding its effectiveness* with respect to *the adoption of these scenarios in "Software Analysis and Design" and "Operating Systems" courses* from the viewpoint of *students* in the context of *Computer Science undergraduate courses at Salvador University (UNIFACS)*". We intend to draw conclusions from the results of this study on how to engage students to be prepared and aware of the challenges and opportunities of cloud computing in the market.

The rest of this paper is organized as follows. Next section presents the context of this work. Section 3 describes the action research study and in Section 4 we analyze the data collected during the study. Section 5 presents the conclusion, threats to validity and scope for future research.

2 CONTEXT OF THIS WORK

Many researchers have argued that the traditional classroom setting has key shortcomings and alternatives such as the flipped classroom have been used with interesting results (Bishop and Verleger, 2013; Williams et al., 2017).

The core idea of the flipped classroom approach is to flip the lecture-based classroom instruction and utilize interactive activities and reading assignments in advance of class (Tucker, 2012). Class time is then used to engage learners in problem-based, collaborative learning and advancing concepts. After class, students can check understanding and extend learning to more complex tasks. Most importantly, the learner has control of the pace and time it takes to learn the material (Green et al., 2017). The Figure 1, adapted from the Faculty Innovation Center [2], illustrates this scenario.

Flipping a class can be a worthwhile approach, especially in courses where the material or processes are traditionally difficult for students to grasp (Williams et al., 2017). And this can be the case of Computer

[2] https://facultyinnovate.utexas.edu/flipped-classroom

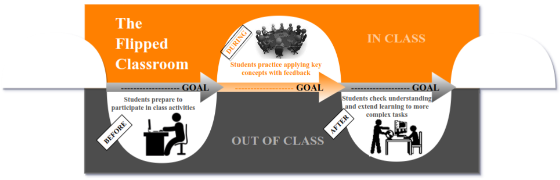

Figure 1: Flipped Classroom (Faculty Innovation Center - Univ. of Texas).

Science Undergraduate courses. Moreover, student-centered, technology-based, and active learning approaches such as flipped classroom relies on students wanting to take control of their learning. This approach enables students to set their own goals, monitor their own progress, facilitating their own and others critical thinking and problem solving skills (Newman et al., 2015).

Today with the advent of DevOps and Cloud Computing, solid knowledge in operating systems is required (Bond, 2015). This reinforces the need for an active learning approach in these courses. On the other hand, the quality of the software product depends directly on the quality of the artifacts produced during the software development life cycle. For this reason, the course of System Analysis and Design plays an important role to consolidate the knowledge regarding the construction of artifacts that describe the problem and register the solution proposed to this problem. Students usually have reported the challenge to understand and register the problem accordingly in artifacts such as use cases or user stories and to derive this information in other artifacts throughout the software life cycle such as class and sequence diagrams (Bahill and Madni, 2017).

3 THE STUDY

In the action research term, *action* refers to improving practice and *research* refers to creating knowledge from the practice experience (McNiff, 2016). When conducting an action research study, the researcher is immersed in the target situation under investigation. The work unfolds in response to the situation and not only to the researchers requirements. Descriptions and theories are built up as a result of the iteration within the context in close collaboration between researchers and participants (Holwell, 2004). The action research steps are iterative and incremental (Hendricks, 2012). Figure 2 shows these steps integrated to the flipped classroom approach.

We used the Goal Question Metric (GQM) approach to plan the action research study. From the research question (**RQ**) presented before, we defined the goals of this study. The goal was then refined into questions that break down the issue into its major components. Each question was in the sequence refined into metrics. The same metric can be used to answer different questions under the same goal. In Figure 3 we show diagrammatically the relationship among goals, questions and metrics of this study. The action research was conducted during the first semester of the academic year of 2017.

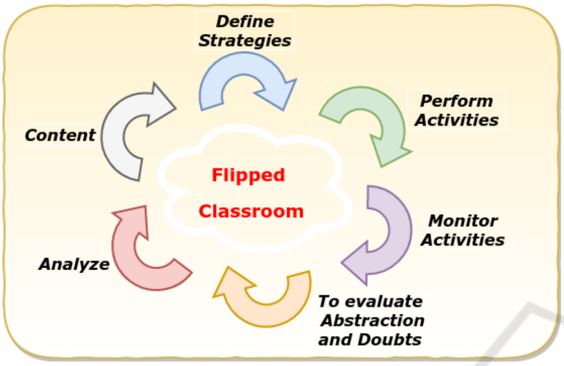

Figure 2: Action Research Iterative Steps. Adapted from (McNiff, 2016).

3.1 Action-Research Planning Phase

The planning phase has two key moments as described below. In the first moment, the course syllabus is the input for the identification of the course characteristics. In the sequence, the set of key cloud resources are indicated as requirements to decide which cloud computing scenarios should be included in the activities. In the second moment, we plan the activities based on the topics/components of the syllabus and contextualized in the selected scenario. We then configure the environment for the execution of the activities in the context of the selected scenarios. An important issue in this phase is the diagnosis of the characteristics of each course, especially the components of the syllabus to promote an effective alignment of the proposed activities with the course goals. It is important to mention that, following the characteristics of an action-research study, the activities created to each course can be adjusted based on feedback provided by the students, researcher or teacher. In these cases, we should return to the Phase 2 of the planning to promote the activities adjustments.

Figure 4 shows the spiral meta-model of the the action-research approach we envisioned to be instantiated in each course. This meta-model is composed of the following phases: planning (green rectangles), execution (yellow rectangle), monitoring, analysis and feedback phases (blue, gray and white rectangles). When conducting the action research study, we repeatedly passe through these phases in iterations (called Spirals). This was needed particularly for the execution of all topics of the course syllabus until the end.

3.2 The Targeted Courses

We decided to conduct the action research study focusing on two courses: *Operating Systems (OS)* and *System Analysis and Design (SAD)* for the following two reasons. The first is the potential to explore the use of cloud resources (Mokhtar et al., 2013) in both courses. The second is the opportunity to illustrate how to perform real activities in the context of topics from the syllabus of the two courses. An operating system is a program that manages a computers hardware. It also provides a basis for application programs and acts as an intermediary between the computer user and the computer hardware (Silberschatz et al., 2014). The Ubuntu Linux distribution was adopted as the operating system to perform the planned activities. This distribution is available in several cloud providers such as Google Cloud [3] and Amazon AWS [4]. Moreover, this distribution is well-known and popular in the open source community [5]. The topics related to process management, memory management, input/output system, and file management are related to operating systems concepts and also enable the use of virtual machines and containers in the cloud.

System Analysis and Design (SAD) deals with planning the development of software systems based on the understanding and specification in detail of what a system should do and how the components of the system should be implemented and work together. The discipline also focuses on identifying characteristics of the software architecture and its components and addresses the concepts of deploy and orchestration of applications in the IaaS layer (infrastructure as a service). Both courses deal with contents that for some extent can require the use of cloud computing capabilities. Therefore, the two courses can be integrated with activities related to cloud computing activities, such as those required for the migration of legacy systems to the cloud.

3.3 Selecting Projects from Github

We used the following criteria to select software projects from Github: Stars, Forks, Contributors, Recent

[3] https://cloud.google.com/compute/docs/images
[4] https://aws.amazon.com/marketplace/pp/B01JBL2I8U
[5] https://distrowatch.com/dwres.php?resource=popularity

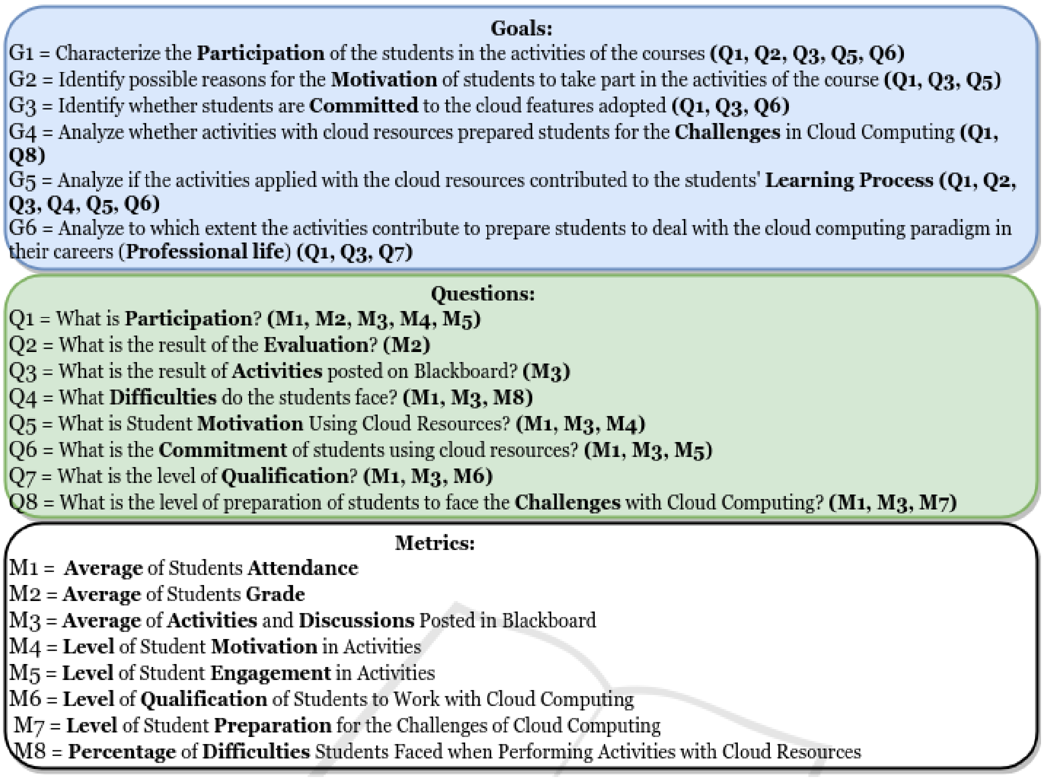

Figure 3: Action Research Goals, Questions and Metrics.

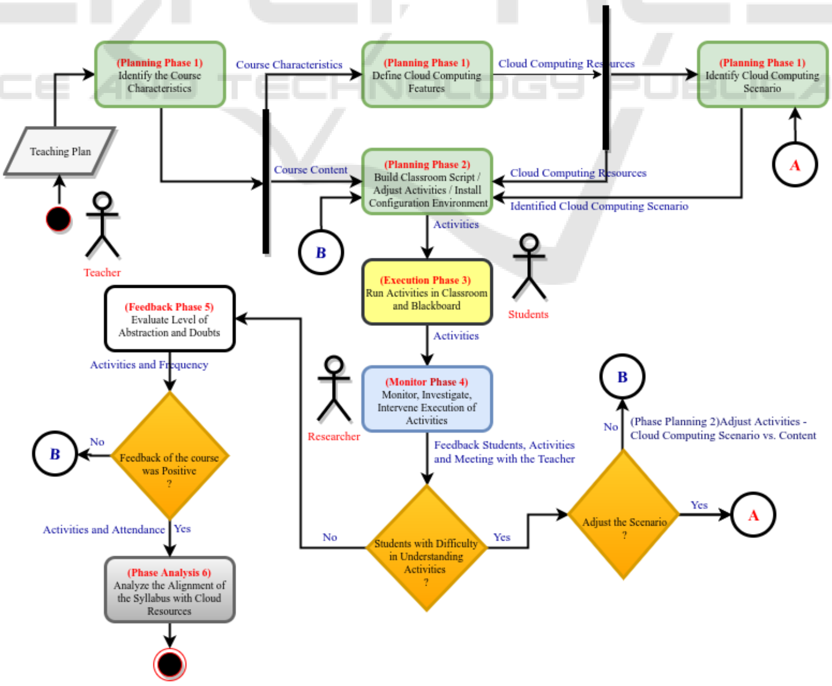

Figure 4: Action Research Meta-model.

Updates, and Open Source Version. These criteria are the same as adopted by (Borges et al., 2016). These projects are used as scenarios for the activities in each course. The selection also considered that they have an installation script and can be accessed/installed in Ubuntu. Table 1 lists the selected projects (Web applications) based on the highest scores in each domain.

3.4 Cloud Scenarios and Activities

We used the virtualization and containers features in the cloud computing scenarios. The virtualization aimed at simulating a remote server that provided cloud services according to the Infrastructure as a Service (IaaS) model.

Table 1: Projects Selected from Github.

Domain	Stars	Forks	Contributors	Updates	Version
Health- OpenEmr	352	490	85	Yes	GNU GPL
Conference Talk- OpenCFP	313	130	50	Sim	MIT
Wine- Nodecellar	14	44	26	Yes	APACHE 2.0
Taxi- App	2	8	5	No	No
Network Monitoring - Zabbix	141	66	1	Yes	GPL-2.0

Scenario 1 - Nodecellar Wine Store (virtual machine and container versions): For the execution of this cloud computing scenario, we used the Cloudify Gigaspaces platform to simulate an application running in the cloud through virtualization (Virtual Box [6]), according to an Infrastucture as a Service (IaaS) model. The Nodecellar [7] is based on Node.js, a JavaScript runtime, to manage (retrieve, create, update, delete) the wines in a wine cellar database [8]. This application has been used by the open source community to demonstrate the steps required to migrate, deploy and orchestrate a legacy application to the cloud.

Scenario 2: OpenEMR (virtual machine and container versions). OpenEMR [9] is an open source electronic health record and medical practice management solution. It can run on Windows, Linux, Mac OS X and several other platforms. Its source code has PHP5+ as programming language, MySQL or MariaDB as database, as well as Apache or other PHP related webserver.

Scenario 3: OpenCFP (virtual machine and container versions). OpenCFP [10] is a PHP-based conference talk submission system that enables the discussion of concepts related to the analysis (problem) and project (solution) in a software system. It also enables the discussion of process management, memory management and input/output management in the context of the operating system course.

[6]https://www.virtualbox.org/

[7]http://nodecellar.coenraets.org/

[8]https://github.com/cloudify-cosmo/cloudify-nodecellar-example

[9]http://www.open-emr.org/

[10]https://github.com/opencfp/opencfp

Scenario 4: Zabbix (virtual machine and container versions). It is an open source enterprise-level software designed for real-time monitoring of metrics collected from remote servers, virtual machines and network devices. This scenario was analyzed in the Amazon Web Services Cloud Service (AWS) through the use of containers (Docker) and Virtual Machines (VM).

Scenario 5: Mobile Taxi Application (virtual machine and container versions). For use of this cloud computing scenario, the artifacts of the mobile taxi-app application are available in the GitHub [11] to discuss the concepts of reverse engineering and UML diagrams.

Scenario 6: Portal Amazon. It is a worldwide online shopping of books, magazines, music, DVDs, videos and many other items.

As showed in Figure 2, the activities to be performed by the students were posted and available in the Blackboard portal of the university. It is a virtual learning environment adopted at Salvador University (UNIFACS) for both face-to-face and distance learning courses. The activities can be reached at the url indicated in this footnote [12].

3.5 Data Sources for the Analysis

We considered data provided by the following sources in this study: (a) Activities registered in Blackboard; (b) Questionnaire on Student profile; (c) Questionnaire for feedback about the adherence of cloud computing scenarios; (d) Midterm and Final Assignment; (e) Student Attendance; (f) Feedback from students during classes and activities; (g) Research and teacher perceptions.

The questionnaires used the Likert scale of 5. No identification was required to answer the questionnaires. Prior to the questionnaires application, we highlighted the importance of the answers to the study and the benefits that the results and findings from these study would bring to better prepare students to the cloud computing market. A total of 13 students in the discipline of Operating systems and 11 students in the discipline of System Analysis and Design completed the questionnaires. The questionnaire for the System Analysis and Design (SAD) students had 35 questions (33 closed and 2 open). The questionnaire for the Operating Systems students had 34 issues (32 closed and 2 open). The closed questions aimed at obtaining the degree of knowledge in the Computer Science field. The open questions aimed at obtaining

[11]https://github.com/mistryrn/taxi-app

[12]https://cloudeduc.github.io/cloudeduc/

Table 2: Goals, Questions and Metrics for SAD Discipline.

	Research issues								
	Q1 Partici-pation	Q2 Evalu-ation	Q3 Activities	Q4 Diffi-culties	Q5 Motivated	Q6 Commi-tted	Q7 Qualifi-cation	Q8 Chall-enges	Results
G1	Partici-pation (64.32%)	(64.80%)	(47%) Low Pro-ductivity	–	Motivated (61.73%)	Compro-mised (61.73%)	–	—	(59.92%)
G2	Partici-pation (64.32%)	–	(47%) Low Pro-ductivity	–	Motivated (61.73%)	–	–	–	(57.68%)
G3	Partici-pation (64.32%)	–	(47%) Low Pro-ductivity	–	–	Compro-mised (61.73%)	–	–	(57.68%)
G4	Partici-pation (64.32%)	–	–	–	–	–	–	Little Prepared (56.61)	(60.47%)
G5	Partici-pation (64.32%)	(64.80%)	(47%) Low Pro-ductivity	Diffi-culties (55.54%)	Motivated (61.73%)	Compro-mised (61.73%)	–	–	(59.19%)
G6	Partici-pation (64.32%)	–	(47%) Low Pro-ductivity	–	–	–	Very little Qualified (40.73)	–	(50.68%)

the perceptions of the students regarding the engagement and what was learned while performing cloud computing related activities.

3.6 Profile of the Students

Both classes have 16 students enrolled in the first semester of 2017. We used questionnaires in May of 2017 to obtain data related to the profile of the students that took part in the action research study. The questionnaire was composed of 15 closed questions. The questions focused on issues related to academic background and knowledge related to cloud computing. The questionnaire can be reached at the same url indicated in the previous footnote.

3.7 The Role of the Authors of the Study

Among the two authors of the study, the second one took the role as the instructor of the two disciplines. He developed lesson plans, conducted face-to-face and online learning activities and participated in all of the action research process. The first author was one of the members of the Monitoring and Support Team (MST). The purpose of MST was to guide the instructor, conduct macro level analysis with the researcher, assess the process, increase the validity and reliability of data collection and analysis procedures, develop functional actions based on findings of the macro level analysis, and to help make the research process as much objective as possible. The MST consisted of 2 experts (the authors) from curriculum, instruction and educational technologies.

4 ANALYZING THE DATA

In this section, we present the analysis of data obtained during the action research study to answer the **Research Question (RQ)**: "Analyze *the use of cloud computing scenarios* for the purpose of *understanding its effectiveness* with respect to *the adoption of these scenarios in "Software Analysis and Design" and "Operating Systems" courses* from the viewpoint of *students* in the context of *Computer Science undergraduate courses at Salvador University (UNIFACS)*". With this analysis we intend to draw conclusions on how to engage students to face the challenges and opportunities of cloud computing in the market. In Figure 5, we show diagrammatically the relationship among goals, questions and metrics. Based on this relationship, we explain first how the metrics were calculated, then we show how they were combined to answer the questions. Finally, we explain the goals. Within one-semester learning process of the proposed inclusion of cloud computing scenarios in the two disciplines, the way students reacted and performed the activities was monitored, as well as the ways students interacted with their peers and with the researchers. Moreover, the ways of interaction emerged during the activity process were carefully analyzed via content analysis.

4.1 Analyzing Data for the SAD Discipline

In the following paragraphs, we analyze data for the System Analysis and Design (SAD) Discipline. We also explain how the values were calculated. In Table 3, we present the values for metrics M1-M8.

Answering the Questions for the SAD Discipline. In the following, we present the calculations for the eight questions aiming at providing conditions to characterize the goals stated in this study.

4.1.1 Question Q1 - Participation of the Students in SAD

According to Figures 3 and 5, the metrics M1-M5 were designated to answer Question Q1. In Table 4, we present the results of metrics M1, M2 and M3 to answer Q1. In Table 5, we present the results of metrics M4 and M5 collected from questions 3.1 to 3.10 of the questionnaire of discipline System Analysis and Design.

Table 3: Collected Metrics for the SAD Discipline.

Metric	Description	Value (Average)
M1	Average of students attendance (Frequency)	89.66%
M2	Assignments Average Value	64.80%
M3	Average of activities/discussions posted on Blackboard	47.00%
M4	Students ' motivational level in activities	61.73%
M5	Level of commitment to students in activities	61.73%
M6	Qualification level of students to deal with cloud computing activities	40.73%
M7	Student preparedness level for cloud computing challenges	56.61%
M8	Percentage of difficulties students had in the activities with cloud resources	55.54%

The value obtained for Q1 of 64.32% classified students from the System and Analysis Design (SAD) as Participatives. This is consistent with the feedback students provided describing their motivation to perform the activities contextualized in cloud computing scenarios.

Table 4: M1, M2 and M3 in SAD Discipline.

Metrics	Description	Average
M1	Average of students attendance (Frequency) (Total 1088h / 112.50h Faltas)	89.66%
M2	Average Rating	64.80%
M3	Average of activities/discussions posted on Blackboard	47.00%

Table 5: M4 and M5 in SAD Discipline - Question 3.1 a 3.10.

Question	Not Approached	Insufficient	Little Enough	Enough	Mote than Enough
3.1	0%	0%	9.09%	90.91%	0%
3.2	0%	0%	9.09%	81.82%	9.09%
3.3	0%	9.09%	0%	90.91%	0%
3.4	0%	9.09%	18.18%	72.73%	0%
3.5	0%	9.09%	45.45%	36.36%	9.09%
3.6	0%	9.09%	72.73%	18.18%	0%
3.7	0%	0%	63.64%	27.27%	9.09%
3.8	0%	45.45%	18.18%	27.27%	9.09%
3.9	0%	45.45%	18.18%	36.36%	0%
3.10	0%	18.18%	45.45%	36.36%	0%
Average	**0%**	**14.54%**	**30.00%**	**51.82%**	**3.64%**

Table 6: Answering Q1 through M1-M5 for SAD Discipline.

Metric	Average (%)	Weight	Result (%)
M1	89.66%	3	268.98%
M2	64.80%	2	129.60%
M3	47.00%	3	141.00%
M4 and 5M	51.82%	2	103.64%
		Average	**64.32%**

4.1.2 Question Q2 - Results of the Assignments/Evaluations - SAD

According to Figures 3 and 5, only the metric M2 was designated to answer Question Q2. In Table 7, we present the results of metric M2 to answer Q2 for the first semester of 2017. We considered the medterm and final exam to calculate M2 to answer Q2. The value of 64.80 is considered regular, near 70 that was the expected result.

4.1.3 Question Q3 - Activities Posted in Blackboard - SAD

According to Figures 3 and 5, the metric M3 was designated to answer Question Q3. In Table 8, we present the results of metric M3 to answer Q3. As can be seen in the table, a participation of 47% in the activities of the course was an evidence that it can be improved. The reason for this occurrence was obtained by feedback in which students declared that also used email and instant message services in their mobile for discussions.

4.1.4 Question Q4 - Difficulties Faced by Students - SAD

According to Figures 3 and 5, the metrics M1, M3 and M8 were designated to answer Question Q4. Considering that M1 and M3 for the SAD discipline were already discussed and listed in Table 4, we present in Table 9 the result for metric M8 as 36.36% related to difficulties faced by students while performing cloud computing activities in the discipline. Considering together metrics M1, M3 and M8, in Table 10 we present the result for Question Q4 as 55.54%. This highlight the challenges faced by students to perform cloud related activities in the context of the SAD discipline. However, analyzing evidence from the students feedback, we realized that despite the difficulties, students strove to achieved the goals.

4.1.5 Question Q5 - Motivation to Perform Cloud Activities - SAD

According to Figures 3 and 5, the metrics M1, M3 and M4 were designated to answer Question Q5. In Table 11, we present the results of metrics M1, M3. The metric M4 is presented in table 12. Considering together metrics M1, M3 and M4, in Table 13 we present the result for Question Q5 as 61.73%. This is considered a regular level of motivation for this discipline with an increasing tendency as verified in the feedback provided by the students.

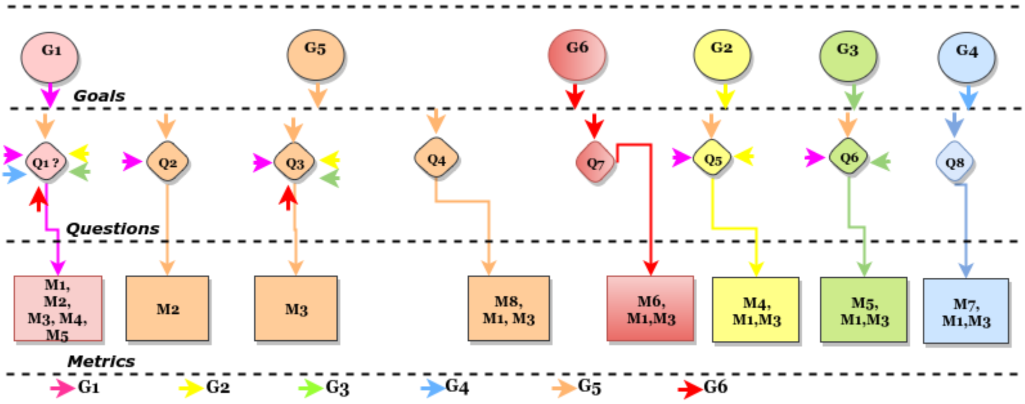

Figure 5: Relationship among Goals, Questions and Metrics.

4.1.6 Question Q6 - Commitment to Perform Cloud Activities - SAD

According to Figures 3 and 5, the metrics M1, M3 and M5 were designated to answer Question Q6. In Table 11, we present the results of metrics M1 and M3. In Table 14, we present the results of metrics M5. Finally, in Table 15, we calculate the value for Q6 as 61.73%. This is an interesting evidence of commitment, reporting that majority of students are engaged in the cloud activities in the context of the discipline.

4.1.7 Question Q7 - Level of Qualification - SAD

According to Figures 3 and 5, the metrics M1, M3 and M6 were designated to answer Question Q7. In Table 11, we present the results of metrics M1 and M3. In Table 16, we present the results of the metric M6. Finally, in Table 17, we calculate the value for Q7 as 40.73%. This value indicates that students have the perception that they need to improve their qualification to deal with challenges and opportunities related to cloud computing in the market. This is in fact an evidence that students are aware of improvement opportunities they need to strive in order to be a qualified professional.

Table 7: Answering Q2 through M2 for SAD Discipline.

k	Average	Frequency	Frequency Relative	Percentage (%)
1	4.0	1	0.06	6
2	4.5	1	0.06	6
3	5.5	1	0.06	6
4	5.8	1	0.06	6
5	6.0	2	0.13	12
6	6.1	1	0.06	6
7	6.2	1	0.06	6
8	6.4	1	0.06	6
9	6.5	1	0.06	6
10	6.8	1	0.06	6
11	7.5	2	0.13	12
12	8.0	1	0.06	6
13	8.4	2	0.13	12
			Average	**64.80**

Table 8: Answering Q3 through M3 for SAD Discipline.

Data	Activities	Scenarios	Participation students(%)
13/03/2017	Activity 1	wiki.openmrs.org	100%
20/03/2017	Activity 2	wiki.openmrs.org	50%
21/03/2017	Activity 3	wiki.openmrs.org	25%
10/04/2017	Activity 4	Taxi App Android	13%
		Average	**47%**

Table 9: Difficulties faced in Activities (M8 - SAD).

Elements	Qty	Percentage(%)
a) Understanding the proposed strategy for using cloud-computing scenarios	4	36.36%
b) Master analysis techniques for Business rules, specification functional requirements, raised/identified/Elicitados	3	27.27%
c) Master analysis Techniques for specification requirements not Func., raised/identified/Elicitados	1	9.09%
d) Elaborate user story, usage cases, usage case diagram, prototyping	2	18.18%
e) Elaborate class diagram	3	27.27%
f) Use virtualization Techniques (virtual machine, Container, images)	5	45.45%
g) Understanding Software Architecture	4	36.36%
h) Elaborate sequence diagram, activity diagram	7	63.64%
i) Elaborate Compoenentes diagram, deployment diagram	7	63.64%
j) Understand the steps of direct/reverse engineering	5	45.45%
k) Using Software engineering tools	3	27.27%
	Average	36.36%

Table 10: Answering Q4 through M1, M3 and M8 for SAD Discipline.

Metric	Average (%)	Weight	Result (%)
M1	89.66%	3	268.98%
M3	47.00%	3	141.00%
M8	36.36%	4	145.44%
		Average	**55.54%**

Table 11: M1 and M3 in SAD Discipline.

Metrics	Description	Value
M1	Frequency (Total 1088h / 112.50h Fouls)	89.66%
M3	Average of activities/discussions posted on Blackboard	47%

4.1.8 Question Q8 - Level of Preparation - SAD

According to Figures 3 and 5, the metrics M1, M3 and M7 were designated to answer Question Q8.

In Table 11, we present the results of metrics M1 and M3. In Table 18, we present the results of the metric M7. Finally, in Table 19, we calculate the value

Table 12: M4 in SAD Discipline.

Question	Not Approached	Insufficient	Little Enough	Enough	More than Enough
3.1	0%	0%	9.09%	90.91%	0%
3.2	0%	0%	9.09%	81.82%	9.09%
3.3	0%	9.09%	0%	90.91%	0%
3.4	0%	9.09%	18.18%	72.73%	0%
3.5	0%	9.09%	45.45%	36.36%	9.09%
3.6	0%	9.09%	72.73%	18.18%	0%
3.7	0%	0%	63.64%	27.27%	9.09%
3.8	0%	45.45%	18.18%	27.27%	9.09%
3.9	0%	45.45%	18.18%	36.36%	0%
3.10	0%	18.18%	45.45%	36.36%	0%
Average	**0%**	**14.54%**	**30.00%**	**51.82%**	**3.64%**

Table 13: Answering Q5 through M1, M3 and M4 for SAD Discipline.

Metric	Average (%)	Weight	Result (%)
M1	89.66%	3	268.98%
M3	47.00%	3	141.00%
M4	51.82%	4	207.28%
		Average	**61.73%**

Table 14: M5 in SAD Discipline.

Question	Not Discussed	Insufficient	Little Enough	Enough	More than Enough
3.1	0%	0%	9.09%	90.91%	0%
3.2	0%	0%	9.09%	81.82%	9.09%
3.3	0%	9.09%	0%	90.91%	0%
3.4	0%	9.09%	18.18%	72.73%	0%
3.5	0%	9.09%	45.45%	36.36%	9.09%
3.6	0%	9.09%	72.73%	18.18%	0%
3.7	0%	0%	63.64%	27.27%	9.09%
3.8	0%	45.45%	18.18%	27.27%	9.09%
3.9	0%	45.45%	18.18%	36.36%	0%
3.10	0%	18.18%	45.45%	36.36%	0%
Average	**0%**	**14.54%**	**30.00%**	**51.82%**	**3.64%**

Table 15: Answering Q6 through M1, M3 and M5 for SAD Discipline.

Metric	Average (%)	Weight	Result (%)
M1	89.66%	3	268.98%
M3	47.00%	3	141.00%
M5	51.82%	4	207.28%
		Average	**61.73%**

Table 16: M6 in SAD Discipline.

Question	No Activity	Little Activity	Activity
Performed Activities	90%	0%	10%

Table 17: Answering Q7 through M1, M3 and M6 for SAD Discipline.

Metric	Average (%)	Weight	Result (%)
M1	89.66%	2	179.32%
M3	47.00%	4	188.00%
M6	10.00%	4	40.00%
		Average	**40.73%**

for Q8 as 56.61%. Similarly to Q7, this value indicates that students have the perception that they need to improve their preparation to deal with challenges and opportunities related to cloud computing in the market. This is in fact an evidence that students are aware of improvement opportunities they need to strive in order to perform effectively cloud related activities.

In Table 2, we summarize the results for all Goals, Questions and Metrics for the SAD discipline.

Table 18: M7 in SAD Discipline.

Question	Not prepared	Very little prepared	Little Prepared	Prepared	Very prepared
5.1	36.36%	27.27%	27.27%	9.09%	0%
5.2	45.45%	18.18%	0%	36.36%	0%
5.3	36.36%	27.27%	27.27%	9.09%	0%
5.4	27.27%	27.27%	27.27%	18.18%	0%
5.5	36.36%	27.27%	9.09%	27.27%	0%
5.6	54.54%	9.09%	36.36%	0%	0%
5.7	36.36%	27.27%	18.18%	18.18%	0%
5.8	18.18%	36.36%	18.18%	27.27%	0%
Average	**36.36%**	**25.00%**	**20.45%**	**18.18%**	**0.00%**

Table 19: Answering Q8 through M1, M3 and M7 for SAD Discipline.

Metric	Average (%)	Weight	Result (%)
1	89.66%	3	268.98%
3	47.00%	4	188.00%
7	36.36%	3	109.08%
		Average	**56.61%**

4.2 Analyzing Data for the OS Discipline

Considering that the Operating System discipline has the same goals, questions and metrics as the SAD discipline and that it follows the sama analysis as presented in the previous subsection, we present Table 22 where we summarize the results for all Goals, Questions and Metrics for this discipline.

4.3 Analysis of the Results of APS and OS Disciplines

In Table 21, we compare the results for metrics M1-M8 for the disciplines SAD and OS. In Tables 2 and 22, we present a panoramic view for the goals, questions and metrics for the disciplines SAD and OS. Analyzing these values, we can conclude that both disciplines have similarities based on their Goals, Questions and Metrics. Hence, despite being different disciplines, they reacted uniformly to the proposed approach that includes cloud computing scenarios in the activities of the disciplines.

4.4 The Engagement of the Students

As can be seen in the results presented in the fields Q5 and Q6 (Motivated/Committed: 61.73% SAD/ 61.91% OS) of Tables 2 and 22, students from both disciplines manifested engagement and also commitment to perform the activities contextualized in cloud computing scenarios. This is an initial evidence that in fact classes in Computer Science undergraduate courses can be enriched with these scenarios when applied using active learning techniques such as flipped classroom to provide students the opportunity to be the main participants in the learning process. On the other hand, teachers can identify improvement opportunities in each student and guide them to fill gaps in topics they are not so confident. This is an iterative and incremental process that can be conducted with real scenarios from the market.

Table 20: Collected Metrics for the OS Discipline.

Metric	Description	Value (Average
M1	Average of students attendance (Frequency)	90.49%
M2	Assignments Average Value	62.50%
M3	Average of activities/discussions posted on Blackboard	46.35%
M4	Students ' motivational level in activities	61.91%
M5	Level of commitment to students in the activities	61.91%
M6	Qualification level of students to deal with cloud computing activities	52.64%
M7	Student preparedness level for cloud computing challenges	56.36%
M8	Percentage of difficulties students had in the activities with cloud resources	52.34%

Table 21: Comparing the Metrics of SAD and OS Disciplines.

Metric	APS (%)	SO (%)
M1 - Average of students attendance (frequency)	89.66%	90.49%
M1 - Average of Students Attendance	64.32%	63.98%
M2 - Average Students Grade	64.80%	62.50%
M3 - Average of the activities/discussions posted at Blackboard	47.00%	46.35%
M4 - Level of Student Motivation in activities	61.73%	61.91%
M5 - Level of commitment of students in the activities	61.73%	61.91%
M6 - Level of qualification of pupils to act with cloud computing (virtualization activities)	40.73%	52.64%
M7 - Level of preparation of students for the challenges of cloud computing	56.61%	56.36%
M8 - Percentage of difficulties faced by students in cloud computing activities	55.54%	52.34%

5 CONCLUSIONS

Software is a fundamental component of many systems, services, and products. Its development consumes increasing amounts of resources. Moreover, an infrastructure is needed to run and make available software to users. The cloud computing paradigm has increasingly provided a better cost-benefit relationship for both the industry and final users. To deal with this scenario, students should be prepared to perform tasks in this scenario. In this paper, we analyzed the inclusion of cloud computing scenarios in two undergraduate courses. As future work, there is the possibility of conducting a new version of this research in collaboration with industry (Hanna et al., 2015), as well as applying the described instruments of flipped classroom and action research approach in industry for training purposes (Fagerholm et al., 2017).Another possibility is the conduction of this study in other universities to compare results and to obtain better conditions to generalize results and findings.

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Table 22: Goals, Questions and Metrics for OS Discipline.

	Research issues								
	Q1 Partici-pation	Q2 Evalu-ation	Q3 Activities	Q4 Diffi-culties	Q5 Motivated	Q6 Commi-tted	Q7 Qualifi-cation	Q8 Chall-enges	Results
G1	Partici-pation (63.98%)	(62.50%)	(46.35%) Low Produc-tivity	–	Motivated (61.91%)	Compro-mised (61.91%)	–	—	(59.33%)
G2	Partici-pation (63.98%)	–	(46.35%) Low Produc-tivity	–	Motivated (61.91%)	–	–	–	(57.41%)
G3	Partici-pation (63.98%)	–	(46.35%) Low Produc-tivity	–	–	Compro-mised (61.91%)	–	–	(57.41%)
G4	Partici-pation (63.98%)	–	–	–	–	–	–	Little Prepared (56.36%)	(60.17%)
G5	Partici-pation (63.98%)	(62.50%)	(46.35%) Low Produc-tivity	Diffi-culties (52.34%)	Motivated (61.91%)	Compro-mised (61.91%)	–	–	(58.17%)
G6	Partici-pation (63.98%)	–	(46.35%) Low Produc-tivity	–	–	–	Very little Qualified (52.64)	–	(54.32%)

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