

A New and Interactive Teaching Approach with Gamification for Motivating Students in Computer Science Classrooms

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Abstract

Higher Education professors and students recognise that the introduction of new tools and learning methods can improve the teaching and motivation to learn. A new interactive and motivating methodology was designed and tested in a real classroom environment. This method, named TechTeach, explored a set of trending concepts applied to teach of Computer Science subjects: BYOD, Gamification, Soft-skills, quiz, and surveys and flipped classrooms to proportionate the best learning environment to the students. The paper presents the teaching plan and the case study used as proof of concept. In the end, it is possible to affirm that the students liked this method and are familiarised with it – most of the answers to the assessment method quiz (87%), was positive.

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1 Introduction

Nowadays, there is a massive difficulty of professors to motivate the students to their classes. Every year new challenges arise (new courses, students and coding languages to teach). Professors cannot domain all the concepts and technologies. So, it is time to change the paradigm. Professors cannot be a person who teaches but someone who explores new trends, ideas, concepts and motivate the students to learn. The use of flexibility, technology and innovation during the teaching process can lead to challenging learning environments [10] and highly motivating. According to [1] “Education, as it is, based on a model of skills, constitutes the development of utilitarian, stratified knowledge, that overvalues preparation for the labour market overtraining for the employment world, in its ontological value”. The learning environments are transformed into flexible spaces that can be locat-ed within or outside the institution [10]. Recent technological developments have given rise to blended learning classrooms [10] that can be motivated by the use of Gamification. Gamification has generated increased attention recently across a range of con-texts [4] as is, for example, education. One of the most relevant changes occurred with the implementation of the Bologna model [1]. The main adjustment went through the development and the acquisition of general and specific skills, according to what professional profiles in the labour market determine [1]. In fact, the way of teaching is changing, and the students are less understanding and supporters of the old school. It is time to join a set of ideas and define a new approach to teach in computer science areas.



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This paper is presenting a new way of teaching in Higher Education. This approach can combine a set of concepts: BYOD, flipped and inter-active classes, interactive quizzes and surveys, soft skills, with a focus in active learning.

The goal of this approach is increasing the interest and participation of students in classrooms by turning it more attractive and interactive. During a semester, this new approach was explored at the University of Minho, and the results are challenging and motivating (87% of positive answers and more than 85% of participation).

This paper is divided into six sections. After a brief introduction, the background presents the main topics of the work. Then, the methodology and the respective case study are presented. After this, results are discussed before the paper being ended at the conclusion.

2 Background

The approach presented in this article involves a set of concepts that it is relevant to explain.

2.1 Bologna Process

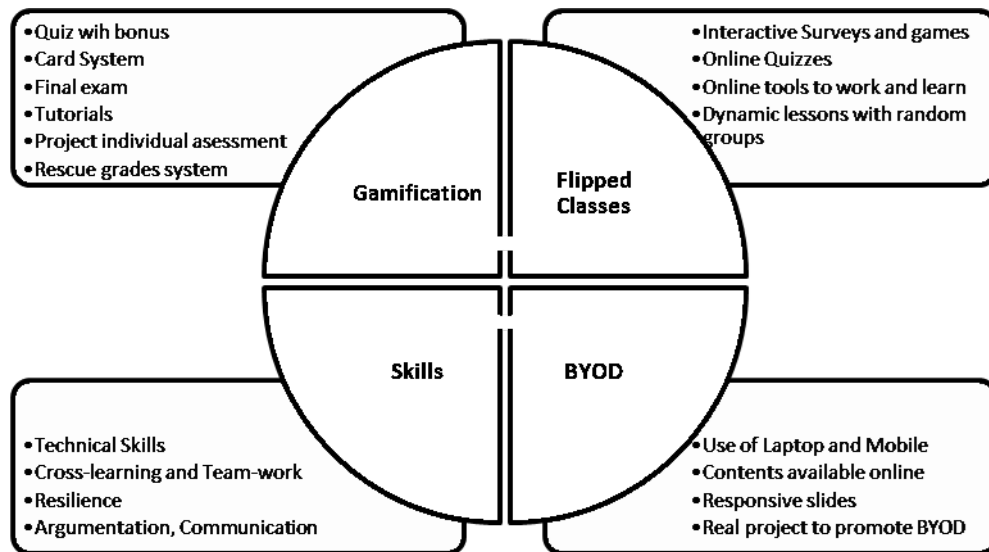
The Bologna Process was signed in 1999 [1] and became a reality of the European educational setting [9]. The objective of this declaration is to create a teaching system easily readable and comparable degrees by allowing promotion of the European dimension in higher education [9]. It is time to follow European directrices and pro-mote a teach from the qualification speech to the model of skills address [1].

2.2 Bring Your Own Device

According Moreira et al. [7] Bring Your Own Device (BYOD) is a subset of the consumerisation of Information Technologies (IT) as private or personally owned IT resources, such as computer device or software that are used for business proposes. In the case of education, BYOD consists of bringing laptops, smartphones or other devices to the classroom in order to increase active learning. Unfortunately, most universities still deliver instruction based on the philosophy of a teacher-controlled learning model that promotes passive learning [3]. This paper has the finality to show different ways of fostering active learners. Using this concept at the classrooms a set of interesting indicators can be collected (e.g. study the impact of the system access with the final grade) [7].

2.3 Flipped learning

Flipped learning is recognised as being an emerging instructional approach that can be used to support the pedagogy of teaching [3]. Learning environments can be any space when the students can learn and not only a classroom where learning is promoted [10]. A flipped classroom consists of using technology to push lectures outside of the school. The learning activities will be used to practice the concepts inside the classroom [12]. In the traditional classes, a lecturer exposes the topics, and then, the students have to do homework activities. In the flipped environment, students need to study and prepare the lesson. They will practice the contents of the week in-classroom activities with the professor and colleagues.



■ **Figure 1** Main concepts of the method.

2.4 Gamification

Gamification consists of “using game-based mechanics, aesthetics and game think-ing to engage people, motivate action, promote learning, and solve problems” [6]. A past study [3] shows that there are several vital points which guide the deployment of the online gamified learning intervention. One research [3] demonstrated that online gamified learning activities have a positive impact on learning outcome.

3 Methodology

The methodology is based on a few numbers of concepts (BYOD, Soft-Skills, Flipped Classes and Gamification) and a set of methods/tasks, as can be observed in Fig. 1 and it is designed to courses with 10 ECTs with theoretical and practical classes.

The following list presents a brief overview of the methodology.

1. Theoretical classes are inverted and should be used to do a brief explanation of the topics and to do practical exercises
 - a. Students must bring their laptop or smartphone to participate in in-class activities.
 - b. Professors are encouraged to promote team-coding exercises.
 - i. These exercises should be executed in a group of 3 students.
 - ii. In each lesson, the groups must be different, and the active programmer must change.
 - c. Each class should have a different learning challenge
 - d. After the classes, the students should fill a quiz (multiple-choice) to assess their knowledge on some of the addressed topics.
2. Practical classes are used to develop a realistic project and stimulate soft-skills
 - a. Each project should address a real problem of society and promote healthy competition between students.
 - b. Projects should be divided into teams and if possible, groups
 - i. A team is composed of a set of groups;
 - ii. Each group should have different roles;
 - iii. The groups are responsible for implementing a set of features

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- c. Project meetings should cross different areas, students and knowledge. The sessions at classrooms should be divided
 - i. By project features (groups)
 - ii. By project roles (teams)
 - d. During the class, the professor should analyse the work done by a student and evaluate their contribution to the project using a gamification system.
 - e. Projects should have three assessment points:
 - i. CP1 - to verify requirements and motivate the students, in a range of three results (10, 15, 20).
 - ii. CP2 - to assess the technical quality of the project.
 - iii. CPF - To assess the final result and the commercial potential.
 - f. The project must include an anonymous peer evaluation using an N+1 scale. Each student should have the possibility to evaluate the contribution of each teammate for the outcome and to propose a project grade.
3. The professor is the “referee and manager” of the class (“game”), he should:
- a. Promote the team learning and the content research – Give some paths and cheats to the result and not provide the final answer.
 - b. Give support to students when they require it and when it is under point a.
 - c. Promote exercises comprising learning of soft skills (resilience, teamwork, public speaking, argumentation, work with uncertain, others).
 - d. Create a list of Frequently Asked Questions (FAQs) with the most common issues verified by the students.
 - e. Create a weekly quiz to assess the students’ knowledge and implement a bonus system able to motivate the participation of students at the classes.
 - f. Display videos able to show what is possible to do after concluding the course/subject. The videos also should explain some area trends and prognostics in the timestamp of five and ten years. Both contents should show the students what they can do in the real world after concluding the course. It motivates the student to participate in the subject.
 - g. Turn available online presentations, videos, documents, practical examples and other essential contents.
 - h. Promote a continuous assessment of the subject and show that the students’ opinion is relevant.
 - i. Implement and define the rules of the rescue system.
 - j. Create Kahoots and games able to promote interactive discussion inside of the classroom.
4. Students are active learner. He is the leading “player” and should
- a. Study the topics before the lesson.
 - b. Explore and learn new concepts
 - c. participate in the “game”, interact with the environment and train their soft-skills.
 - d. Win points to achieve better grade possible.
 - e. Contribute for the cross-learning and improvement and assessment of the CUnit.

A critical point of this article is not to show the methodology but explain how it can be applied in a real context.

4 Case Study

The methodology presented in section 3 was tested at the University of Minho during the first semester of 2019/2020 in the course unit (CUnit) of Web Programming (WP). This CUnit has more than one hundred (100) students, ten (10) ECTs and occurs during 20 weeks with 15 weeks of contact. Weekly, each student has the following hours:

- Theoretical (T): 2.
- Theoretical-practice (TP): 2.
- Laboratory (LP): 2.
- Non-presential: 7.

4.1 Week plan

The following list presents the most relevant tasks of CUnit plan grouped by weeks:

1st week – presentation of the CUnit and implementation of a quiz to understand the class environment and students' profiles.

1. **T**: A Kahoot quiz was used to:
 - a. Know student's opinion about the type of CUnit (Inverted or Normal). The answer compromises the student with the process.
 - b. Understand the student's expectations and their situation in the class.
2. **TP**: Videos about the future of web programming are used to motivate the students.

2nd week – flipped lessons started (in **T** lessons)

1. A set of exercises is proposed by class.
2. Students are invited to seat in different places to ensure a group of three random members.
3. During the class, the professor goes to each group, explaining some parts of the code.
4. When some critical issue is detected, the professor interrupts the exercises and explains it to everyone.

3rd week – the project is presented (in **TP** lessons).

1. The project is about to create a system capable of supporting the development of outdoor activities (e.g. karting, rafting, orientation, others).
2. A set of thematic was presented, and each team has chosen one of them. The project is divided into three packages of features:
 - a. Administration of the Outdoor Activity company.
 - b. Mobile App to the participants.
 - c. Management of the spaces company and sponsors activities.
3. A group of students develops each package. Every group has three areas: Front-end, Back-end and full-stack.
4. Each team has to prepare a contract document to delivery to the professors containing the project requirements and its cost (the final grade that they desire).

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4th week – the strategy of practical classes is defined.

1. **TP:** All teams work grouped by project roles; for example, all the full-stacks worked together.
 - a. The full-stacks are responsible for ensuring the correct development of the project and connecting Front-end and Back-end.
 - b. A set of roles are defined: Product Owner (team leader), Group Manager (one for each package) and Area Manager (one for each area).
 - c. Students are motivated to define a week plan and share their experiences and difficulties during the group development.
2. **LP:** Each team works divided into groups in order to develop the respective features (packages).
 - a. Students share the decisions taken, and tasks defined at the roles' meetings early occurred in LP classes.
 - b. The development follows the rules defined by the team during LP classes.

5th week – Quiz is launched.

1. A quiz about the topics discussed in each T is available to students answer after the class.
2. A bonus system is implemented
 - a. The quiz is available to all the students that meet the T class.
 - b. At each class, a set of students (between 5 and 15), is randomly selected to have the bonus.
3. Each quiz is composed of a set of questions with a limit of 100 points. Selected students have their result doubled (in case of 75 points, they receive 150).

7th week – the yellow and red card system is implemented.

1. **LP:** The participation of each student at the practical component is evaluated using a gamification card system.
 - a. A student can receive until two yellow cards. After that, they receive a red card and are reproved at the practical component.
 - b. This system is used as an alert system for the students. They can know that they are not working enough, and if the student goes one like this, they will reprove at the CUnit. Otherwise, they receive the alert and improve their work.
2. The professor of laboratory classes starts the analysis of the project and can surprise the students by chosen someone to show what he did until the moment.
3. Professors ask the students about the work done, and, in case of the work done is none or too reduced, they admonished the student with a yellow card.
4. **T:** During the class, the professor shows the current probability of having a final exam. In the same lesson, he used a survey to collect the students' opinions about the CUnit performance and expectations until the moment.

10th week – Professor asked students about their opinion (2nd round).

1. **T:** Several questions were made regarding the CUnit: methods, professors and classes.
2. This Kahoot survey is essential to understand the student's opinion during class.
3. Students can rescue the grade achieved in the handwriting test

11th week – Handwrite test

1. Students show what they know or learned
2. This test is individual and wants to test the basis of front-end and Back-end
3. There is no syntax validation; only the concept and idea are tested. In real-world, they can use anything to help them; however, they need to know how to start.
4. This test is used as a cut-off (binary result), i.e., some students are ready to continue, others not.

12th week – Rescue system is activated

1. Students who were surprised by the Handwrite test and think that he knows more than the grade can show, they can rescue the MT classification.
2. The rescue system can maintain the student in the “game”; however, he needs to show more than the others. In this system, a particular focus is put in those students. Then, in case of success at the end, the final grade of MT is multiplied by 90%.

15th week – A Game Group was developed recurring to Kahoot (T lesson).

1. All groups competed in order to be the best team.
2. The game is composed of 20 questions about the subject lectured. In the end, the students of the three best groups receive a bonus in the participation grade.

During the classes, students faced out some type of soft-skills challenge. For example,

- (a) They had to work with different colleagues every week at T classes;
- (b) Professors did not say all the answer but some part only. Students were encouraged to work with the uncertainty and look for solutions in internet, slides or books;
- (c) TP classes are distributed by team roles (back-end, front-end and full-stack)
- (d) LP classes are organized by group and project features.
- (e) Project work (team and individual) are evaluated by all members of the group using a peer assessment tool (available at ioEduc).

After the method being introduced, the tasks and jobs continue in the following weeks. Next section presents the weeks with assessment points.

4.2 Assessment points

The control points of the project occurred for three weeks: eight (**CP1**), twelve (**CP2**) and seventeen (**CPF**). **CP2** and **CPF** had an individual and peer assessment.

Each student submitted their opinion about the grade of the group and the performance of each student. The degree of each group member varies from $n-4$ until $n+4$. The sum of all notes needs to be zero. For example, a group with a project of 12 can have students with 8 (-4) and others with 16 ($+4$). In case of a student did not work or worked less than 25% their colleagues can signalise him. The work of signalised students is then analysing by the professor and can be converted into a red card.

In CP2 and CPF, the professor can attribute yellow and red cards. A direct red card can be assigned in the case of a student being incapable of proving that they worked in the project or justify why they did not work. After CP2, the working plan is adjusted according to the remaining members.

Individual knowledge of each student is assessed through three mini-tests (MT) were designed. Each one was designed to evaluate:

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- (a) Front-end matters (Moodle test with a pool of questions).
- (b) The basis of front-end and Back-end (handwrite code test without having consult and syntax validation).
- (c) The entire content of CUnit (Moodle test with a pool of questions).

An algorithm was created to find the possibility of the students having an exam (percentage from 0 to 100) at the end of the semester. This algorithm used a Likert Scale [11] from 1 to 5 and took in the attention of six aspects:

- (a) The motivation of the students (Positive)
- (b) Preparation to the classroom (Positive)
- (c) Noise during the lesson (Negative)
- (d) Fatigue of the professor at the end of class (Negative)
- (e) Meet of Class Goals (Positive)
- (f) Hoarseness (Negative)

This algorithm is calculated at the end of each T class. Then, the students can know the probability of having an exam in three weeks: 6, 10 and 14. After the fourteen-week, students will see the final decision. In case of the percentage be upper to 50% exam will occur; otherwise, there is no exam.

4.3 BYOD Platform

A new tool named ioEduc¹ [8] was used to motivate interaction and learning. ioEduc is a Progressive Web APP (web/mobile platform) [5] designed to support teaching activities [7]. This platform was created by the author of this paper and then implemented by IOtech. ioEduc applies the concepts of Bring Your Own Device to classrooms and has a set of features / allow a set of tasks:

- (a) Making student attendance at the classroom
- (b) Taking notes of the lessons
- (c) Rescue grade system
- (d) Reading the slides (responsive system)
- (e) Assessing the teammates work
- (f) Creating teams and groups of projects
- (g) Consulting the drive and the FAQ system
- (h) Accessing to a real-time and offline chat (messaging system) with the professor.

For complementing the work, interactive classes are promoted using AWS C9² – “AWS Cloud9 is a cloud-based integrated development environment (IDE) that lets you write, run, and debug your code with just a browser [2].

- Parallely students were instigated to explore and deploy their project using
1. GitHub³ – is a development platform inspired by the way you work. From open source to business, you can host and review code, manage projects, and build software alongside 40 million developers.
 2. Heroku⁴ – is a platform as a service (PaaS) that enables developers to build, run, and operate applications entirely in the cloud.

¹ <https://ioeduc.iotech.pt>

² <https://aws.amazon.com/cloud9/>

³ <https://github.com>

⁴ <https://heroku.com>

■ **Table 1** Description and goal of each class.

Type of Class	Description	Goal
T	Theoretical classes in groups of three students (random). Flipped classes. Discussion and analysis of the week topics. Exercising and practising examples.	Practice the concepts learned at home before class. Encourage group discussion and difficulty analysis; Share knowledge and experiences with different teammates.
TP	Students are grouped by team and area/role. The tasks of the project are defined.	Team working, test soft-skills, Promote the discussion, team learning and cross-learning
LP	Develop in a group, the tasks defined by the team. Monitoring of the project; Individual evaluation of the work (IEW). Support and monitoring the development of group projects, including feedback on their status;	Control Point - Monitoring and Evaluation of Project Status Motivate team working. Identify the students who are and are not working according to the rules.
Non-Presential	Reading, study and analysis of slides and CUnit book. Systematization of the concepts, principles and methods presented. Preparation for the next lectures. Development of a group project. Participate in the quizzes of topics.	Explore the capability of self-learning and studying something new. Assess the students' knowledge.

One of the most substantial aspects of this CUnit is the professors' accessibility. During the entire CUnit professors were available to help students after the classes by email. A chat is accessible in ioEduc to facilitate the communication between students and professor among the class.

4.4 Quality assessment of the UC

All the students are invited to evaluate the CUnit and participate in the definition of CUnit during the classes. They are asked to participate in interactive surveys (Kahoot) by answering questions about the performance of Professors, Type of Classes, Motivation, Expectations, among others. The assessment surveys are performed at the begin (1st week), middle (6th and 10th week) and end (15th week) of the course.

5 Discussion & Results

To a better comprehension of the CUnit plan, 1 presents the description and goal of each type of class (T, TP, LP).

The CUnit was assessed recurring three methods: Participation, Theoretical and Practice. Participation is assessed by the results achieved with the quizzes. The Mini-Tests evaluate the theory, and practice is measured through the project. Each method has a percentage associated. Participation has a particularity that it is essential to mention, the best grade without bonus has the maximum degree. For example, if the higher number of points without bonus is eight-hundred and fifty (850), this student will have twenty (20). All quizzes (with a

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■ **Table 2** Learning and assessment methods.

Method	Group	Goal
Surveys / Kahoots	BYOD Flipped Classes	Assess CUnit performance Ask students about their opinion Promote games and interactive discussions during the class
Card System	Gamification	Alert the students about their performance
Quiz	Flipped Classes	Assess assimilation of week concepts
Bonus	Gamification	Motivate students to participate in classes.
Project	Skills	Assess technical and soft-skills
FAQ	Flipped Classes	Help the students with the most common questions
Handwrite test	Knowledge Skills	Assess the expertise of doing the basis without help and syntax validation
Drive	Flipped Classes	Help the learning process with white papers, tutorials and examples
Rescue system	Gamification	The possibility of rescue a grade when the students think that he deserves more.
Game	Gamification BYOD, Skills	Play in the group, be fast, assess team knowledge and win points
Challenges with random groups	Flipped Classes BYOD, Skills	Promote the discussion and team learning
Final exam	Flipped Classes Gamification	The existence of the final exam is the responsibility of the students.

bonus) having a result higher than eight-hundred and fifty also has twenty, and all the other students have their grade in the percentage of 850. In this phase, it is essential to know the methods used to turn this subject more attractive and interactive.

In Table 2, it is possible to see the methods used and the goal of each method. For example, Yellow Card System was used to alert the student about their performance in the project. FAQ and drive were used to complement the teaching and give some tips and tutorials to students.

The methodology implemented in the Web Programming class was assessed. A survey using Kahoot and containing several questions was presented to the students in the last week (15).

Table 3 highlight the most relevant topics regarding the assessment methods. The survey was answered by ninety-three students (93), and the answers range from:

- (a) negative | weak.
- (b) neutral | acceptable.
- (c) good | interesting.
- (d) true Positive | excellent.

As can be observed in Table 3, most of the answers were positive (87% of the responses had 3 or 4 points). Regarding assessment methods, several tools can be explored.

■ **Table 3** Final survey answer.

Question	1	2	3	4
Adequacy of strategies and methodologies adopted by the teacher	2	12	40	25
Work environment created	0	6	44	32
UC Global Appreciation – Theoretical	1	11	44	24
Overall, I appreciate UC	1	5	30	34

6 Conclusion & Future Work

Reflecting the transformations associated with the Bologna Process, it had worldwide proportions and has been raising various opinions [1]. It changed the way of teaching, and new strategies were defined. Besides that, the world is growing fast, and professors need to be ready for those changes. It is essential to invest in new ways of motivating students and promote the training of soft-skills.

Regarding the case study presented in this paper, a set of soft-skills was successfully trained:

- (a) Problem Solving
- (b) Decision Making
- (c) Responsibility
- (d) Cross-Learning
- (e) Positive Attitude
- (f) Resilience
- (g) Team Working
- (h) Communication
- (i) Negotiation
- (j) Reflection & Clarification
- (k) Influencing
- (l) Commitment
- (m) Dealing with Aggression
- (n) Stress Management
- (o) Listening Skills
- (p) Counselling Skills
- (q) Presenting

New technologies and methods were implemented to motivate students and promoting continuous and active learning:

- (i) Gamification used to drive participation, evaluate students' involvement in the classes and their intervention on the project.
- (ii) Project and flipped classes used to improve skills.
- (iii) BYOD was put in practice using a PWA named ioEduc.
- (iv) Continuous assessment of the CUnit performed by the students.
- (v) Rescue system available to students contest the grade
- (vi) Hand-write test used as a cut-off system to assess the student has minimum knowledge required.

This paper showed new approaches that can be explored in computer science classrooms. Presented approach wants to motivate professors to explore different strategies to create active learners instead of following a traditional method. The scientific community should look to 2 as some examples of what can be done and take ideas to their classes. Professors should be confident and believe it works, and students will like.

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This methodology revealed to be a success. The percentage of attendances at classes was around 85%, and 87% of the answers provided in the last quiz were classified as good or excellent. Achieved results demonstrate the students' interest and propensity to this type of classes.

In terms of digital lessons and online learning, this method will also be improved to consider non-presential classes. Although this new situation promoted by COVID19 brings new challenges, TechTeach can be easily adapted to a different type of lesson (synchronous or asynchronous). You can use, for example, ioEduc to share the slides online and online meeting tools (e.g. zoom, collaborate, team, among others,) to going along with the working group. You can also use Kahoot and ioEduc to provide the assessment tests. The extended version of this paper will explain how you can transit your teaching activity to a non-presential environment.

In the future, new mechanisms will be implemented like white and blue cards, new gamification process or new methods of theoretical assessment. In the sequence of this paper, an extended version will be published. The extended version will have a depth analysis of the student's opinion. Regarding to digal lessons and online learning, this method will also be improved in order to consider non-presential classes

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