

## Article

# Cloud Computing Technology and PBL Teaching Approach for a Qualitative Education in Line with SDG4

Mohammed Airaj <sup>1,2</sup> 

<sup>1</sup> Department of Electrical Engineering and Computer Science, National School of Applied Sciences, Sidi Mohamed Ben Abdellah University, Fez 30000, Morocco; mohammed.airaj@usmba.ac.ma

<sup>2</sup> L2IS, Faculty of Sciences and Technologies, Cadi Ayyad University, Marrakech 40000, Morocco

**Abstract:** This paper explores teaching–learning models in this period of the COVID-19 pandemic at Cadi Ayyad University (UCA). It investigates success conditions for e-learning quality education in higher education in line with SDG4, the 4th Sustainable Development Goal: “Ensure inclusive and quality education for all and promote lifelong learning”. This paper demonstrates that an approach of technology alongside teaching could positively impact academic teaching–learning in higher educational systems, leading to an approach focused on humans that aims to cultivate critical thinking, knowledge creation, argumentation, and creativity. This paper concludes with a proposed machine learning model to predict contribution factors to student learning success.

**Keywords:** cloud computing; project-based learning; e-learning; machine learning; SDG4



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## 1. Introduction

The COVID-19 pandemic has put a strain on higher education institutions, forcing universities to quickly review their teaching practices. However, the COVID-19 crisis has come at the right time to redesign the models of teaching in depth, aiming toward a truly flexible and efficient qualitative education; an education focused not just on learners but also on the learning environment, content, processes, and outcomes produced at the lowest level of resources [1]; an education helping to reduce inequalities and to reach gender equality; an education that empowers people everywhere to live more healthy and sustainable lives; an education that fosters tolerance between people and contributes to more peaceful societies [2]. In the context of the current pandemic, we can observe that in several countries, from different universities and different disciplines, many learning courses in higher education are provided on cloud computing based tools, whether on learning management systems (LMS) of the Moodle type with their tools, quizzes, and homework assignments or collaboration tools such as Microsoft Teams and Google Meet [3–8]. Other learning platforms supporting the transition to e-learning are also used. Platforms such as Coursera or Udemy have strategies to cover the entire spectrum of higher education and continuing education. Massive Open Online Courses (MOOCs) have made it possible to democratize knowledge, by offering entire online courses and training. It is worth noting that cloud computing-based technology has been widely used in the educational system across the world during the COVID-19 pandemic. Scientific literature supports this trend. In [9], the authors found that a significant paradigm shift has occurred in the education system post COVID-19 outbreak, considering digital learning to be the new way of learning worldwide. E-Learning and cloud-based technology are the latest models to have been widely adopted in the educational field [10]. There is a necessity of using cloud computing in educational systems [11]. The development of e-learning application models based on cloud computing will continue to proceed at a rapid pace; indeed, e-learning will usher in a new era of cloud computing [12]. The authors in [13] studied the impact of combining cloud computing and big data technology on online learning, with a particular focus on students’ learning behavior data, which can provide the decision-making basis for online

learning and teaching analysis. In [14], based on the Google cloud computing platform, the authors designed their own online learning system to improve the integration of online learning information resources and facilitate interaction between teachers and students. In an analysis of new digital technologies that could solve the problems arising in education at present, and in order to develop the most effective university digitalization policy, the authors of [15] proposed the use of gamification (24%), cloud computing (22.3%), working with big data (20%), 3D printing (14.3%), adaptive design (12.7%), and wearable technologies (6.7%). In other studies, cloud computing has been combined with other methods and technology in a new solution to enhance e-learning. Cloud computing can motivate students by following an experiential education approach, using unique gaming techniques or collaborative e-learning platforms [16]. EvalSeer gamified LMS implements a hybrid approach and use of gamification. EvalSeer aims to keep the students motivated and enable them to quickly and continuously develop their programming skills [17]. Cloud computing combined with virtual reality enables students to simulate physical presence [11]. In other research, the authors proposed a cloud-to-end rendering and storage system to provide a high-quality 3D experience with low latency for experimental education [18].

In [19], the authors applied cloud technologies to construct an expert system, showing that a combination of various disciplines can result in an application convenient for educational activities and for conducting distance lessons. The authors predict a sustainable educational environment based on cloud technology in the coming years. Other studies propose a feasible mobile cloud computing adoption model. In one such study, the authors believe that by adopting the concept of mobile cloud computing, organizations can enhance productivity, irrespective of their geographic location during challenging times, such as the days of COVID-19 [20]. In [21], the authors found that 5G wireless communication technology, artificial intelligence, and cloud computing have played effective roles in prevention and monitoring during this epidemic emergency. In [22], the authors provide a comprehensive review of 5G technology with the integration of other digital technologies (such as AI and machine learning, IoT objects, big data analytics, cloud computing, robotic technology, and other digital platforms) in emerging healthcare applications.

However, the findings from [23] reveal that technological and environmental factors have an impact on the intention of public universities to adopt cloud computing. The study underlines that security concerns are a significant reason for the reluctance of these universities to adopt cloud computing. In [24], it was reported that the responsibility to maintain a high level of security rests with both the end users and the cloud computer server. The authors of [18] proposed an education in a cloud environment in a more secure manner and with better performance. Data is first compressed and then encrypted on the sender side. At the receiving end, the data is decrypted and decompressed.

Meanwhile, in [25], along with a Project-Based Learning (PBL) orientation, the authors introduce the Fully Online Learning Community (FOLC) model, which currently serves as the basic modality for many of the courses in the fully online programs offered by the Faculty of Education and Faculty of Health Sciences at Ontario Tech University. Ref. [26] contributes to the domain of skills acquisition, reporting that during the COVID-19 pandemic, despite social distancing, students' virtual communication skills can be achieved through online learning using a modified PBL through WAG and Zoom meetings. Ref. [27] aims to develop an Edmodo application and Zoom-based online learning resource with PBL models for accelerated linear motion material. This type of research represents educational research and development with the ADDIE model (analysis, design, development, implementation, and evaluation). Ref. [28] explores students' readiness towards PBL online learning in two subjects of Physics among Physics students from Universiti Malaysia Sabah. Online learning was implemented through the PBL approach in two subjects: Thermodynamics Physics and Statistical Physics, during Semester 1 and 2, respectively.

From the literature cited above, we can see that the pairs (cloud computing, e-learning) and (PBL, e-learning) have been explored in different ways, with the aim to enhance student learning success. In this study, we aim to combine cloud computing with PBL in e-learning

to provide a qualitative education. PBL is a pedagogical approach that involves learners in knowledge construction by accomplishing a real-world project. Actually, there is a wide range of design models that attempt to embed learning within real-world contexts, such as problem-based learning, case-based learning, project-based learning, inquiry-based learning, cooperative (work- or community-based) learning, and learning by doing [29]. In PBL, students work independently in teams while teachers work as facilitators rather than instructors, giving sufficient attention to students' points of view and supporting them in the learning process. Students' autonomy in learning and knowledge construction promotes their learning skills and innovation capabilities [30]. By nature, PBL outcomes are affective, cognitive, and behavioral; they are affective in the sense of perceptions of benefits and experiences, cognitive in the sense of knowledge and cognitive strategies, and behavioral in the sense of skills and engagement [30,31]. It has been shown that as a learner-centered education, PBL positively affects teachers' self-efficacy. Analysis using student data from Korea indicates that positive responses from students may mediate the association between PBL and teachers' self-efficacy [32]. At UCA, our courses are organized into lectures, hands-on activities, and working projects [33], with traditional pedagogy based on instruction for lectures and hands-on activities, and project-based learning (PBL) pedagogy for working projects. Our experience in PBL was our savior in this pandemic, with students having already gained some independence and autonomy in learning, and showing some ease in adaptation to e-learning. Students and teachers have agreed that PBL was successful before this pandemic and continues to be so thereafter. Working on projects was not affected when switching from offline to e-learning. Our experience shows that PBL and agility are important pedagogical concepts for e-learning success. Here, agility means reacting rapidly to changes, making decisions at the right time, having experiences at regular intervals, receiving regular feedback from stakeholders (students, teachers, and administration), making corresponding adjustments, and looping. Without the pressure of COVID-19, e-learning courses would look quite different. There would be a strong focus on developing new online pedagogy, developing PBL, and deploying cloud computing technology to enhance e-learning.

This study, therefore, aims to answer the questions:

- How could cloud computing, PBL, and e-learning together contribute to learning success?
- Based on the survey data, how can we develop a machine learning model to predict contributions to learning success from pedagogy, technology, and teaching strategies?

## 2. Materials and Methods

### 2.1. Context

In this section, we present online teaching–learning models adopted by UCA University for the teaching–learning process. Then, necessary conditions and initiatives for qualitative teaching–learning success are discussed.

#### 2.1.1. UCA E-Learning Models

Morocco, a developing country in North Africa and member of the MENA group, is not an exception to what is happening everywhere due to COVID-19. UCA Moroccan universities have adopted protocols [34] to ensure the continuity of remote pedagogical activities for their students. UCA has adopted different education policies. UCA's enormous challenge was keeping students and employees (e.g., staff, administrators) safe from COVID-19. Considerations were taken to help protect students and employees and slow the spread of this virus. Different policies were adopted depending on the cycle of study: first cycle or second cycle. The first cycle is the bachelor's degree; the second cycle is the master's degree and graduate diploma.

- A hybrid learning model was adopted for master and graduate students. Students participate in small, in-person classes, spaced at least 1 m distance apart, with increased space between desks in the classroom. There are in-person lectures when possible, with hands-on activities and online projects. Exams are held in person,

while project presentations are conducted online. A decision is automatically made to suspend in-person classes for one week if two students in the same class test positive for COVID-19. E-learning is assured during the suspension time.

- An e-learning model was adopted for 1st- and 2nd-year undergraduate and bachelor students because of their high number, schedule, and limited number of classrooms.

### 2.1.2. UCA E-Learning Organization

To prepare the teachers of each institution to record lecture videos, UCA has classrooms in its institutions which are equipped with touch screens and digital desks. UCA also equipped studios that can be used outside a course's slot (there are seven studios available at UCA in addition to two mobile units). Teachers wishing to stay at home are requested to record their video lectures on their own. It is also possible to record a PowerPoint or PDF presentation video, with the camera deactivated, for teachers who do not want to be visible. Computers were made available to teachers who did not have one during this time of crisis. Once the video lecture is recorded, it is mandatory to make it visible on the Moodle platform, in the place specified for the course at the date/time of the appropriate session in accordance with the course planning. For ease of use, UCA developed explanatory videos on how to use the Moodle platform for students and teachers. Technical units at each UCA institution provided training for teachers on how to use Moodle and Microsoft Teams for online teaching and online evaluations and quizzes (See Table 1). Regarding teacher–student communication, UCA administration has been very active in ensuring that all students have active academic accounts at “edu.uca.ma”, having also created two mailing lists (Students and Faculty) for ease of communication. The Students mailing list is for Institution/Study/Semester/Group, while the Faculty mailing list is for Institution/Department/Study, in addition to the discussion forum UCA created for this purpose. UCA has also encouraged communication via social networks and solicited regional radio to offer time slots during which courses and conferences could be given (See Table 2).

**Table 1.** UCA institution organization.

	Monitoring unit:
	- regularly monitoring the course schedule and the situation of online courses.
Institution	Communication unit:
	- answering students' questions.
	Technical unit:
	- digitizing course materials;
	- supporting teachers in recording their video lectures.

**Table 2.** UCA presidency organization.

	Monitoring and communication unit:
	- preparing press releases;
	- ensuring daily exchanges with the ministry;
	- coordinating the entire operation.
Presidency	Technical unit in charge of the organization of the UCA Moodle platform:
	- supplying power for the platform;
	- setting up servers.
	Technical unit:
	- creating academic addresses;
	- setting up groups;
	- monitoring the quality of the network.

Organization of teams in the form of work units was another important thing. In order to monitor and ensure proper execution, several teams have been created and organized in the form of units at two levels: institution and presidency.

### 2.1.3. E-Learning Platforms

UCA deployed an LMS platform (<http://learn.uca.ma/>, accessed on 22 September 2022), based on Moodle, for each of its institutions. This platform is used by teachers to upload material online, by module and in accordance with the timetable and the available teaching pedagogical supports. This is in addition to the existing pre-Covid Uc@Mooc platform (<http://mooc.uca.ma/>, accessed on 22 September 2022) and UCA's YouTube channel (<https://www.youtube.com/UCAMOOO>, accessed on 22 September 2022) with over 500 authentic and reliable videos. The university has also encouraged teachers who use handwritten lectures to put them in digital or PDF format, PowerPoint presentations, etc. In addition, the university deployed the 'UCA Contact' platform to facilitate communication via SMS or email. YouTube is used as a channel for courses, and Facebook for communication; other SNSs are not seen by UCA as platforms that could be used for teaching. UCA students who are very familiar with SNSs created Facebook groups for each course of study, where they communicate, share resources, and help each other, without intervention from teachers and far from their sight. Furthermore, in these groups, they can ask help from their experienced predecessor graduate students. Having LinkedIn profiles has greatly helped them to find internships in these times of crisis, and can also help them find jobs internationally.

### 2.1.4. Necessary Infrastructure for E-Learning

A condition necessary, but not sufficient, for the success of e-learning is having a good internet connection throughout urban and rural areas. In Morocco, the "Agence Nationale de Réglementation des Télécommunications" (ANRT) official agency publishes reports on Information and Communication Technologies (ICT) indicators for households and individuals. The last two reports, published in 2019 and 2020, concern internet usage (2019) and telecom infrastructure (2020) for households and individuals [35,36]. Table 3 presents the most important indicators that could help e-learning to succeed in Moroccan universities.

**Table 3.** Infrastructure and internet usage in Morocco (2019).

Hardware/ Software Network	Individual	Household	Rural	Urban
Mobile phone	-	99.8%	-	-
Smartphone	A total of 75.7% of individuals are equipped with a mobile phone. The 5 to 39 age group is the most equipped with smartphones, with equipment rates ranging from 80% to 88%.		-	-
Computer/Tablet/ Laptop	Young people aged from 9 to 24 are the most equipped.	60.6%	-	-
Mobile Application	-	60.6%	-	-
Social Networks	A total of 94.7% of individuals use applications on smartphones; 97% of them are young people aged from 12 to 24. Social networks, games, and access to news are the main uses. Overall, 96.4% of internet users access social networks. This use is widespread, regardless of age and gender. Among them, 80% are WhatsApp users. Internet users use social networks on a daily basis. Young people between 12 and 24 years old frequently use social networks on a daily basis.	-	-	-
Internet Access (Mobile, ADSL, Optical Fiber)	There is intensive use of the internet, especially on smartphones.	74% overall; 40% of households say their children under the age of 15 use the internet	60%	80%
Mobile Internet	-	70%	-	-

We consider mobile networks and internet networks to be distributed well enough in urban and rural areas in Morocco. There is intensive use of the internet among individuals of different ages, children and young people included, both male and female, with no

distinction of gender. Social networks are leading the way. There has been a rise in computer equipment and laptop dominance. There is strong enthusiasm for mobile internet access among households. The majority of individuals are skilled in using social network applications, which has helped in implementing e-learning. As stated in the 2020 report [36], a large part of the population considers the internet to be of primary importance in their daily life: 75% in professional life, 62% in personal life.

Whilst UCA students come from different socio-economic backgrounds, students from rural environments dominate, which constitutes a peculiarity of the academic area of UCA. With a particular focus on students in social precariousness, UCA negotiated with telecom operators the possibility of offering a free connection to students so that they can access the e-learning platform for a limited time and thus be able to download their courses. This made it possible to provide students with a Virtual Private Network (VPN) connection allowing access to the e-learning platform. With this solution implemented, students now have access to university data, but not the whole internet. This solution required the transfer of the courses available on YouTube to the local servers of the university. Regarding drawbacks, we lost cloud-based security, and the ease of deployment and scalability that comes with hosting our material on the cloud. However, the literature is not in agreement on this aspect [37]; cloud-based LMSs provide protection against hackers and viruses, but only allow higher education institutions to have limited control over the data, so privacy and data security are not verified. Actually, VPN connections to UCA servers increased the data connection; in response, UCA provided an additional fiber optic internet for each institution. Monitoring and maintenance of the quality of the data connection is assured by the technical unit.

#### 2.1.5. E-Learning Pedagogy

During these times of crisis, we have experienced the same online teaching environment as described in [3–8]. In addition, from our experience, students were asked not only to mute their microphones and post questions in the online chat, but also to turn off their camera as it consumes a lot of data connection, which could impact online lecture delivery. Students were allowed to ask questions during and after online lectures. Sometimes there is no interaction from students during online lectures, nor after in Microsoft Teams chats, which creates confusion in teachers' minds. The solution to this problem is to ask the students to complete a quiz after each online lecture, making it possible to check their understanding and also to maintain engagement. Apart from quizzes after lectures, teachers need a way to receive regular feedback from students about e-learning and make corresponding adjustments, in order to be more agile and achieve satisfactory results over time. Students and teachers have both experienced problems due to slow internet connectivity, especially students in rural areas. Sometimes, network crashes happen, creating stress and anxiety. Stress and mental health for students and teachers during this pandemic has not been given the importance it should be; UCA lacks counseling services for both students and teachers, which is not conducive to helping maintain their mental health. Psychological disruption could have a negative impact on students' learning and motivation.

#### 2.1.6. E-Learning Evaluation and Assessment

During this time, 1st- and 2nd-year undergraduate student evaluation has been carried out online in the form of an MCQ Exam on the Moodle LMS platform. Students have free internet access via VPN to Moodle. Open-book exams have been adopted. Access to documents is granted during this type of exam assessment. It is a different story for higher degrees; in master's and engineering degrees, learning is in hybrid mode, evaluation is in in-person exam form, and project presentation is either online or offline for those using project-based learning. Not all instructors use exams as an assessment technique.

Open-book exam experience is very questionable; many questions have raised concerns about fairness and equity. There is an absence of human or program invigilator,

cameras and microphones are off, and there is no way to register student device IP addresses nor geographical location. Students who want to could cheat in different manners, for example, by asking for help from a comrade or an expert, or even paying an expert to pass an exam on their behalf. Consequently, fairness for honest students decreases when using open-book online exams through the Moodle LMS, as there is no way to identify cheating.

## 2.2. Sample

### 2.2.1. Project Methodology

We defined small units (teams) of work. The students ( $n = 25$ ) were organized in six teams, each one composed of four people, except for one composed of five. The teams are cohesive and composed of students with similar ability and interest in the topics being learned. On precedent courses, every student has gained skills in agility regarding the development of software. The role of scrum master is rotated, as is the role of tutor and tutee, so everyone experiences these roles. To prevent misinformation, teachers monitor discussions between tutors and tutees. The duration of each sprint varies, normally ranging between one and four weeks, with a trend towards shorter sprints. We decided to use a two-week sprint. Teams used AWS EC2 and MS Azure free student accounts to develop, test, and deploy their applications. All students participated in the evaluation process regarding the impact of the combined use of cloud computing and PBL on e-learning success. The students were in their third-year software engineering degree enrolled in a distributed systems course. Demographic data show that 96% of the sample were male participants, whereas 4% were female participants. This distribution can be considered as an inadequate gender balance in our sample, because in the particular case of Morocco, men tend to prefer technical careers. The sample average age is 22.36, standard deviation 0.70, minimum age 21, and maximum age 23. All of them are from Morocco, except for one student from Mali. The students developed a PBL project as part of the course assignments.

Sample size calculation is a very important component in research. Sometimes we end up with very small sample sizes due to our failure to anticipate non-response [38]. Small sample sizes occur in various research experiments and especially in preclinical (animal) studies due to ethical, financial, and general feasibility reasons. Often, less than 20 animals per group are involved, thus making valid inferences in these studies challenging [39]. Some areas of neuroscience make statistical inferences on individual subjects [40]. On the other hand, in [41], the authors argue that some of the most robust, valuable, and enduring findings in psychology were obtained not using statistical inference on large samples, but using small-N designs in which a large number of observations are made on a relatively small number of experimental participants [41]. In addition to the small sample sizes, repeated measurements as well as multiple endpoints are often observed for the experimental units (animals), naturally leading to a “large  $p$ , small  $n$ ” situation and thus to a high-dimensional data design [39]. Through the careful selection of appropriate statistical tests, meaningful conclusions may be drawn from studies with small sample sizes [42]. In our case, the size of our sample is small ( $n = 25$ ), due to the fact that the number of students in the Moroccan engineering graduate diploma curriculum is very small. These are very selective courses, access to which is made after selection, admission, competition, and oral interview. The students developed a PBL project as part of the course assignments.

### 2.2.2. Project Evaluation

We assessed the team work and the produced applications by considering the following evaluation levels:

- Lecturer: Distributed systems lecturer continuously monitored artifacts produced by each team. In particular, IceScrum, and Git helped to monitor the progress of teams and to assess whether they respected fixed deadlines.

- Project presentation/demonstration: Each team presented their work and gave a demonstration to a panel formed by students, lecturer, and the teaching staff. Each team of students had to show their results, use cases, lessons learned, and best practice.
- Questionnaire: The students were asked to respond to a questionnaire to evaluate the combined cloud-based PBL e-learning methodology. The questionnaire included a section about sociodemographic data (sex and age) and items about the project. The questionnaire included questions about cloud computing, PBL, Reciprocal Peer Tutoring (RPT), agile methodology, and SNSs. The questions focused on interaction/communication, critical thinking, problem-solving, knowledge management, comprehension and understanding, argumentation, and discussion aspects. The participants responded using a five-point Likert-type scale, from 1 (totally disagree/poor) to 5 (totally agree/excellent). The questionnaire included two open-ended questions about valuable aspects and suggestions for improvement.

Three evaluation techniques were used for the evaluation of this combined strategy: lecturer evaluation; a project evaluation survey; and presentation of the project process and implementation and lessons learned to a panel formed by students, lecturer, and the teaching staff.

### 3. Results

#### 3.1. Positive Aspects of Cloud Computing

Students in general said that cloud computing is useful and easy to use. They also identified high availability, load balancing, and debugging aspects of cloud computing. However, while most students (56%) felt that data privacy and security are fair, 12% felt that data privacy and security in cloud computing are poor (Figure 1).

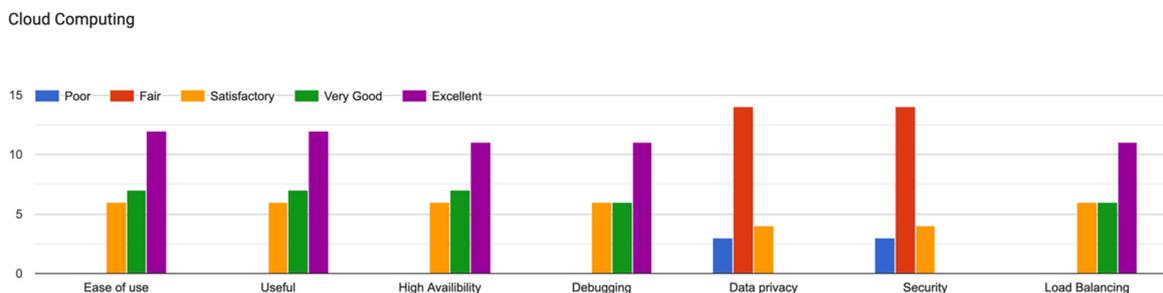


Figure 1. Impact of Cloud Computing.

#### 3.2. Positive Aspects of PBL

Overall, 84% of students agreed (20% strongly agreed) that PBL cultivated their critical thinking, developed their creativity, enhanced their knowledge, augmented their comprehension and understanding, and enhanced their problem-solving skills (Figure 2).

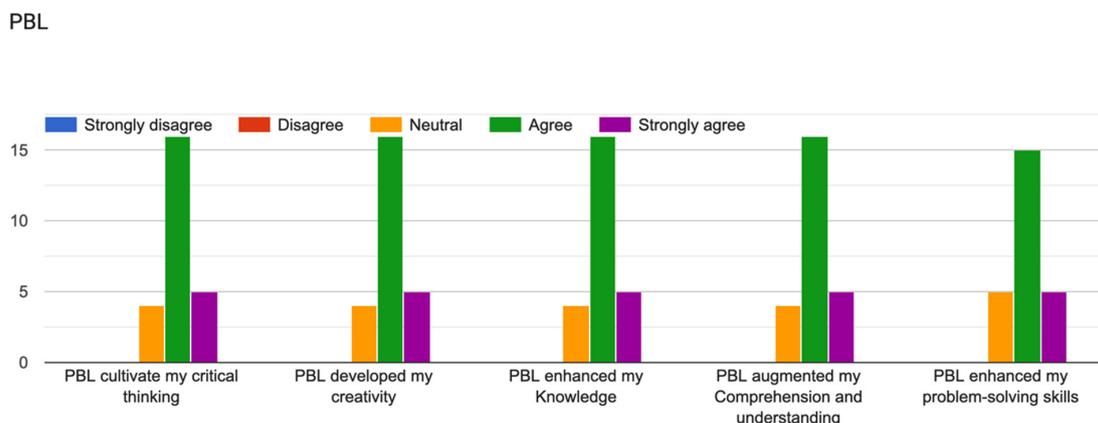


Figure 2. Impact of PBL.

### 3.3. Positive Aspects of RPT

Around 60% of students agreed (8% strongly agreed) that RPT was crucial in supporting communication, argumentation, discussion, and knowledge construction within their teams, while 24% disagreed and 8% were neutral (Figure 3).

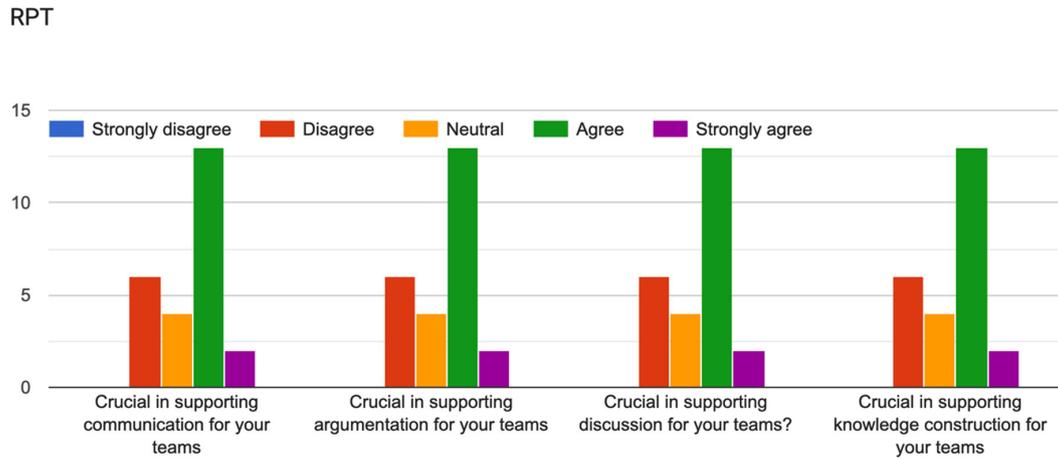


Figure 3. Impact of RPT.

### 3.4. Positive Aspects of Agile Methodology

Overall, 68% of students agreed (4% strongly agreed) that the agile methodology iterative aspect improved their understanding, while 20% disagreed and 8% were neutral (Figure 4).

#### Agile methodology

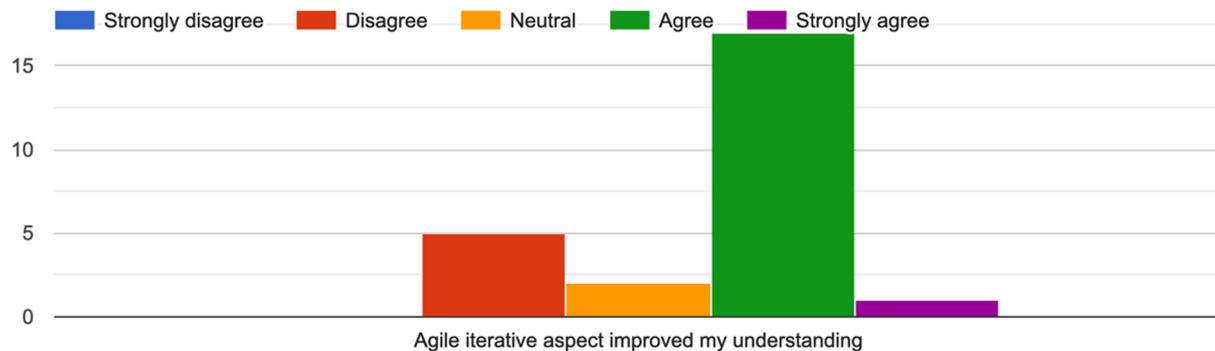


Figure 4. Impact of Agile methodology.

### 3.5. Positive Aspects of Combining Technology and Pedagogy

More than 90% of students said that cloud computing and PBL are the most critical to their project success. Agile methodology was critical for 68%, and RPT for 56% (Figure 5).

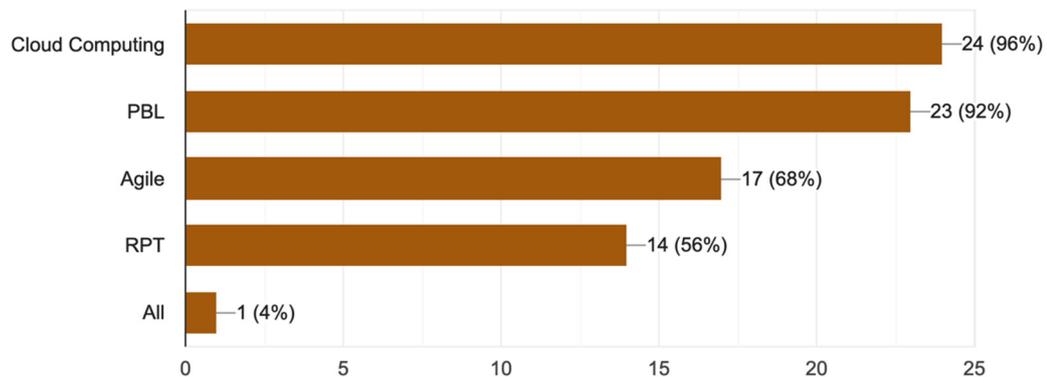
### 3.6. Prediction of "Contribution to Learning" Attribute

In this section, we visualize the data to gain insights, prepare the data for machine learning algorithms, select a model and train it, and then fine-tune our model. Our model's output will be a prediction of a "Contribution to Learning". Our features are "Cloud Computing", PBL, RPT, and "Student Learning Effort". It is a supervised learning task since we have labeled training examples, a regression task as we are asked to predict a value, and a univariate regression problem as we are trying to predict a single value for each student. A typical performance measure for regression problems is the Root Mean

Square Error (RMSE). Using Euclidean distance, it gives an idea of how much error the system makes in its predictions, with a higher weight for large errors.

### What's most critical to the success of the project?

25 responses



**Figure 5.** Impact of Cloud Computing, PBL, RPT, and Agile.

#### 3.6.1. Correlation Matrix

Figure 6 plots every numerical attribute against every other numerical attribute. We can clearly observe that the points are not overly dispersed. In addition, there is some cap clearly visible as a horizontal line at some points in some curves; this is probably due to data quirks. It is hard to see any particular pattern in the data visualized in the scatter plot in this figure. However, since our dataset is not too large, we can easily compute Pearson's  $r$  (standard correlation coefficient) between each pair of attributes (Figure 7).

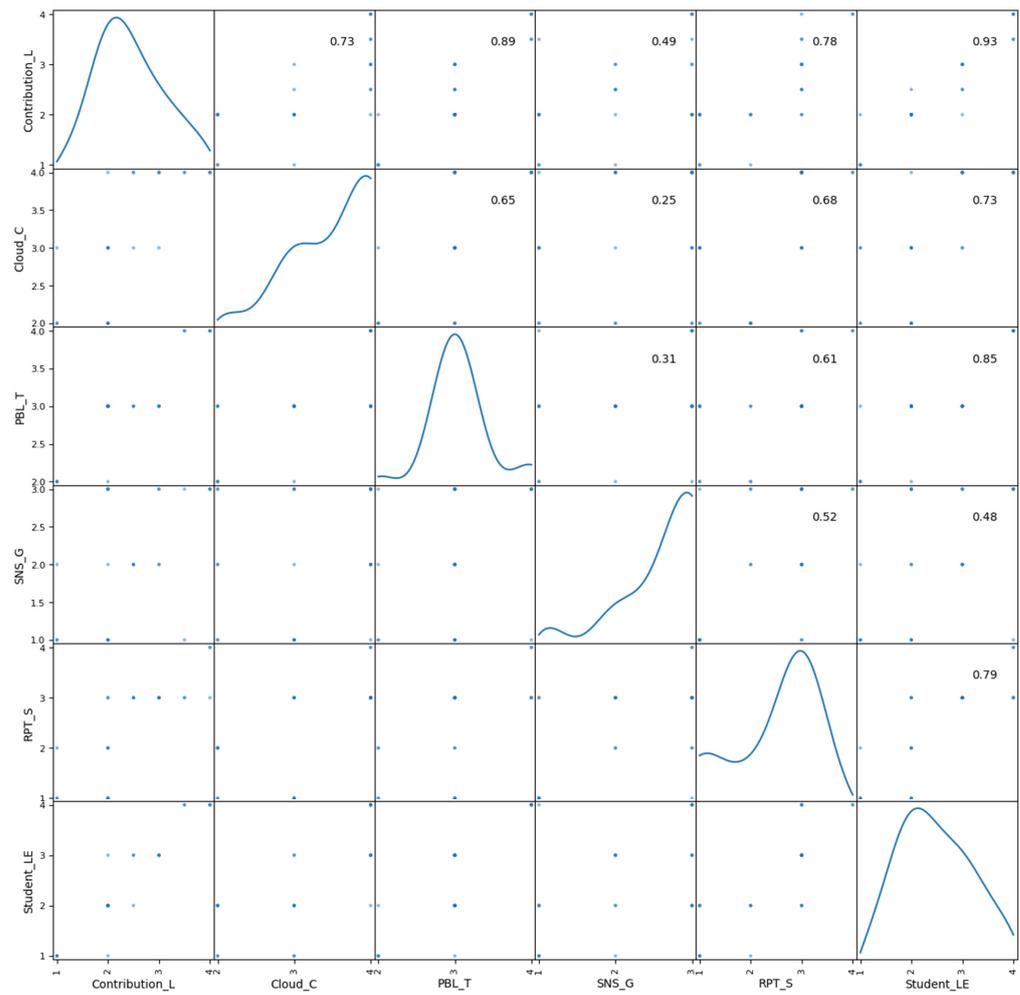
This plot reveals that the correlation is indeed very strong between "Contribution to Learning" and "Student Learning Effort" (0.93), "Contribution to Learning" and PBL (0.89), "Contribution to Learning" and "Cloud Computing" (0.73), and "Contribution to Learning" and RPT (0.78).

#### 3.6.2. Selecting and Training a Model

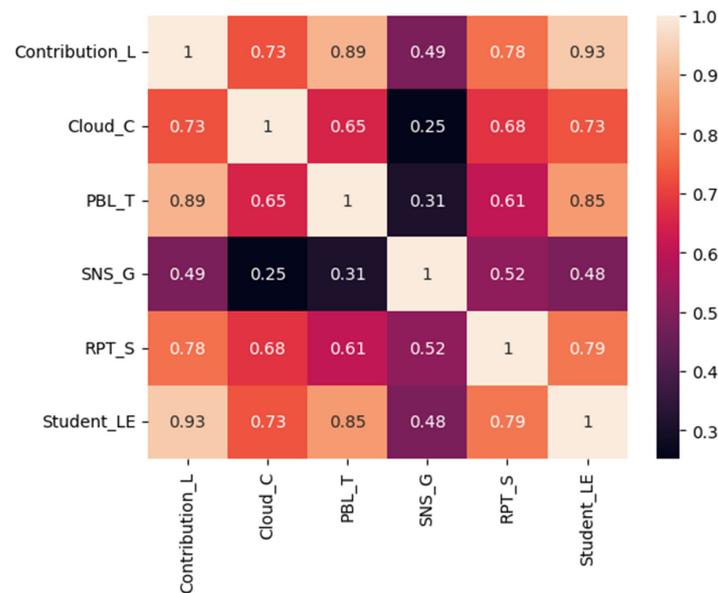
We begin by sampling a training set and a test set, putting the test set aside, and making sure we are only exploring the training set. As most machine learning algorithms cannot work with categorical attributes and missing features, we must convert categorical attributes from text to numbers, and also replace NaN values with median values. Once the data is cleaned, we need to select and train a machine learning model.

In order to select a machine learning model, based on RMSE for the whole training set, we will compare the evaluation of training a Linear Regression model (simple model), Decision Tree model (complex model), and Random Forest model (complex model).

As shown in Table 4, we achieved a great score for each algorithm. However, sometimes, a model could underfit or overfit the training data. One way to evaluate them better is to use cross-validation. To evaluate our models, the idea is to split the training set into a smaller training set and a validation set, and then train our models against the smaller training set and evaluate them against the validation set. Better than that, we have used Scikit-Learn's K-fold cross-validation feature, randomly splitting the training set into ten distinct subsets called folds, and then training and evaluating our models five times, picking a different fold for evaluation every time and training on the other four folds. The results are shown in Table 5.



**Figure 6.** Scatter matrix plotting every numerical attribute against every other numerical attribute, plus a density of each numerical attribute in the diagonal.



**Figure 7.** Pearson's r between each pair of attributes.

**Table 4.** Evaluation of ML algorithms against our data using RMSE measure.

	Linear Regression	Decision Tree	Random Forest
RMSE	0.2628184956399891	0.11180339887498948	0.17980813269519633

**Table 5.** Evaluation of ML algorithms against our data using cross validation and RMSE measure.

	Linear Regression	Decision Tree	Random Forest
RMSE Mean	0.33345375655509946	0.5806643756761883	0.4160890030464608
RMSE Std	0.20080483724190562	0.22434099674509428	0.17373659185490511

However, note that the score for the training set (Table 4) is still much lower than for the validation sets (Table 5), meaning that the model is still overfitting the training set. Possible solutions for overfitting are to simplify the model, fine-tune it (regularize), or collect much more training data.

### 3.6.3. Fine-Tuning Our Model

We have used the Grid Search method to fine-tune our models. We told Scikit-Learn's Grid Search which hyperparameters we want to experiment with and what values to try out, which used cross-validation to evaluate all the possible combinations of hyperparameter values (see Table 6).

**Table 6.** Hyperparameter grid for each model.

	Linear Regression (Ridge)	Decision Tree (DecisionTreeClassifier)	Random Forest (Gradient-BoostingRegressor)
Hyperparameter grid	'alpha': [0.0001, 0.001, 0.01, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 20, 50, 100, 500, 1000]	'max_features': ['auto', 'sqrt', 'log2'], 'ccp_alpha': [0.1, 0.01, 0.001], 'max_depth': [5, 6, 7, 8, 9], 'criterion': ['gini', 'entropy']	'learning_rate': [0.01, 0.02, 0.03, 0.04], 'subsample': [0.9, 0.5, 0.2, 0.1], 'n_estimators': [100, 500, 1000, 1500], 'max_depth': [4, 6, 8, 10]

Table 7 presents the RMSE score for the best combinations, which is slightly better than the score we obtained earlier using the default hyperparameter values for linear regression, and much better than the score we obtained earlier using the default hyperparameter values for Random Forest.

**Table 7.** Evaluation of ML algorithms against our data using RMSE measure.

	Linear Regression	Decision Tree	Random Forest
RMSE	0.22525566673988778	1.1832159566199232	0.3613084076410328

## 4. Discussion and Conclusions

In this paper, the UCA model of teaching–learning during this pandemic period is considered. We show that the problems encountered are similar to those encountered in some other universities in other countries and different fields. Models of learning range from e-learning, to face-to-face learning, to hybrid-learning. Switching from one model to another was dictated by the evolution of the pandemic situation and the protocol defined by each country. Early lessons learnt from e-learning experience during the beginning of this pandemic are needed for a new teaching approach adapted to the e-learning environment.

As e-learning is a remote learning approach, it is necessary, but not sufficient, to have a developed network infrastructure in both rural and urban areas, and students and teachers equipped with smartphones, tablets, and/or laptops connected to the internet. LMICs, and specifically low-income countries, suffer from the digital divide between rural and urban

areas. For some students in a difficult socio-economic situation, this could lead to early stopping or disruption of their learning, with consequences for their mental health. In an ideal world, users would have computing capabilities anytime, anywhere, using almost any device [15]. Mobile cloud computing could help in ensuring equitable access to distant computing resources.

In this paper, we explore the value of combining cloud computing technology with PBL, RPT pedagogy, and agile methodology with respect to qualitative e-learning in higher education. The main contribution of this study is the combination of PBL and cloud computing as a teaching and learning strategy that provides an easy to use and useful technology combined with a teaching approach that enhances critical thinking, creativity, knowledge, comprehension and understanding, and problem-solving skills. The explored survey data show a strong correlation between “Cloud Computing”, PBL, “Student Learning Effort”, and “Contribution to Learning”. We also show that other pedagogies and methodologies added to this combination could improve results for some students. SNSs, enhanced with pedagogical strategies such RPT (correlation 0.78), could help in student–student communication, knowledge creation, knowledge construction, and argumentation skills. Agile methodology, for most students, improved their understanding, in a way that could help with receiving regular feedback from students and make corresponding adjustments, in order to be more agile and to achieve satisfactory results over time.

Regarding the first question of the study, and unlike other proposals that chose to combine cloud computing and e-learning, or PBL and e-learning, the combination of the triplet (cloud computing, PBL, e-learning) was proposed. The implementation was possible due to the participation of students in the e-learning process during COVID-19. Moreover, the study attempted to examine the students’ perceived success and effectiveness of this combination of learning and teaching techniques.

The second objective of this research was a machine learning model to predict “Contribution to Learning”. In order to construct this model, we framed the problem, collected the data and explored it, sampled a training set and a test set, and cleaned and prepared the data for machine learning algorithms. Then, we evaluated machine learning models by comparing them with respect to RMSE measure, with fine-tuning conducted through GridSearch and RMSE.

Our contribution lies in the fact that the combination of cloud computing and PBL, as expressed in the evaluations, may enhance critical thinking, creativity, knowledge, comprehension and understanding, and problem-solving skills. We demonstrate that PBL combined with cloud computing could immediately benefit current practitioners from various software development parties. Moving towards cloud computing, adopting PBL will produce more qualitative educational services at a lower cost and with higher quality. This study shows that e-learning combined with cloud computing and PBL helps combat inequalities in access to knowledge, improves human capacities and skills, and contributes to offering a qualitative education in line with UN SDG 4 (the 4th Sustainable Development Goal).

Finally, it should be acknowledged that the sample used corresponds to a specific region of Morocco, and thus, the results obtained may not be transferrable to other populations across the globe. This fact should encourage researchers to repeat similar studies, collecting data from different regions across the globe and comparing them. In addition, our sample size ( $n = 25$ ) is small. One remedy in future research is to repeat the same study on the same population, but on multiple courses, leading to a “large  $p$ , small  $n$ ” situation and thus to a high-dimensional data design.

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