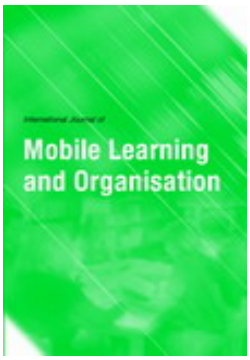

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Andrea Sofia Cornejo Paredes, Alexander Acuña Ramírez, Beatrice Cueva Medina, Aremi Isabel Paja Medina, José David Esquicha Tejada, José Alfredo Sulla-Torres

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Andrea Sofia Cornejo Paredes,
Alexander Acuña Ramírez,
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José David Esquicha Tejada and
José Alfredo Sulla-Torres*

Universidad Católica de Santa María,
Urb. San José s/n Umacollo,
Arequipa, Perú
Email: 74048310@ucsm.edu.pe
Email: alexander.acuna@ucsm.edu.pe
Email: 75910710@ucsm.edu.pe
Email: 71768410@ucsm.edu.pe
Email: jesquicha@ucsm.edu.pe
Email: jsullato@ucsm.edu.pe
*Corresponding author

Abstract: Learning by putting our knowledge into practice is one of the best ways to impact our learning positively; where students or university graduates can put their knowledge into practice, gaining more experience and confidence to face the world of work, this can be achieved through a challenge-based methodology supported by intelligent technologies such as chatbots integrated into a mobile application. The objective is to create a mobile application using a personalised chatbot based on challenges to support students' development. The proposal allows the creation of an ecosystem between universities, companies, and students. For the development of the mobile app, the agile scrum methodology was used together with lean startup for the workflow of the development group. The results show that it was possible to develop a mobile application that integrates learning based on challenges with a chatbot to encourage innovation in university students in an acceptable way, which was validated in terms of usability with the Brooke system usability scale (SUS) instrument, in 83% and with the ISO 9126 software quality tests with a real value of 79. Therefore, it is concluded that developing a mobile application that integrates challenge-based learning fosters innovation in university students.

Keywords: challenge-based learning; methodology; innovation; mobile application; chatbot; scrum.

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Biographical notes: Andrea Sofia Cornejo Paredes is an Information Systems student at Universidad Católica de Santa María since 2019. With four years of practical experience in creating intuitive software experiences, she has honed her skills during her tenure at IBM. Her research interests primarily focus on usability, user experience, and the Internet of Things (IoT). She has gained valuable insights and hands-on experience in developing solutions that prioritise user needs. Her combination of academic knowledge and practical expertise positions her as a valuable contributor in the field of information systems, driving meaningful innovation and user-centric solutions.

Alexander Acuña Ramírez is a final year student of Systems Engineering at Universidad Católica de Santa María, in Arequipa, Peru. With a strong interest in web development and a keen eye for UX/UI design, he is dedicated to creating engaging and user-friendly digital experiences. Proficient in various programming languages and web technologies, he strives to combine his technical skills with a deep understanding of user-centred design principles. He stays up-to-date with the latest industry trends, attending workshops and actively seeking opportunities to enhance his knowledge. Committed to professional growth, he aims to contribute to impactful web projects.

Beatrice Cueva Medina is an exceptional ninth-semester student at Universidad Católica de Santa María. With a keen interest in UX/UI, she has actively engaged in research projects and collaborated with professors and peers. With 2 years of experience in the field, her passion lies in creating intuitive and engaging digital experiences. Beatrice intends to continue her impactful contributions to research in information systems and interface design, showcasing her dedication and talent in the field of UX/UI.

Aremi Isabel Paja Medina has been pursuing her studies in Systems Engineering at the Universidad Católica de Santa María since 2019. In 2021, she gained hands-on experience in working with virtual environments and simulations as an active member of the Virtual Human Simulation Laboratory at Pontifícia Universidade Católica do Rio Grande do Sul. Her research interests revolve around the utilisation of augmented reality and virtual reality within 3D virtual environments. Additionally, she dedicates her efforts to seeking technological solutions for environmental problems, while continuously exploring innovative approaches to enhance UX/UI designs in her professional practice.

José David Esquicha Tejada is a Systems Engineer from the Universidad Catolica de Santa Maria, UCSM in 2008. He holds a Second Specialty Professional degree in Systems Auditing and Information Security at UCSM (2019). He has an MS degree in Strategic Telecommunications Management at the Miguel de Cervantes European University in 2013. He is a PhD of Environmental Sciences and Renewable Energies at the Universidad Nacional de San Agustín de Arequipa in 2022. He is currently an Assistant Professor at UCSM in the Faculty of Physical and Formal Sciences and Engineering. His research interests include the internet of things (IoT) and educational technology.

José Alfredo Sulla-Torres is a Systems Engineer from the Universidad Católica de Santa María, Perú, UCSM in 1997. He has a Professional degree in Education and a Second Specialty in Software Engineering in 2015. He has a Master's in Systems Engineering and a PhD in Computer Science from the National University of San Agustín de Arequipa, Perú in 2018. He is currently

a full-time Research Professor at the Universidad Católica de Santa María. His research interests include artificial intelligence, mobile technologies and technologies applied to health.

1 Introduction

The purpose of this study is to serve as a support to address one of the most critical challenges faced by students and university graduates when putting their knowledge into practice. Universities have traditionally focused on curriculum-based master classes and single evaluations, which do not necessarily prepare students for real-world situations or the demands of the job market (Ausín et al., 2016). Many companies are now seeking graduates with up-to-date knowledge and soft skills, such as working in teams and interacting appropriately with others (Schaeffer et al., 2018).

To address this issue, the study proposes the development of a mobile application that allows the publication and management of fundamental academic and business challenges. This mobile application will be developed by integrating challenge-based learning (CBL) methodology (Nichols and Cator, 2008). CBL is a learner-centred approach that focuses on solving real-world problems, leading to research or innovation that contributes to the country's and society's development (Duarte de Krummel, 2015). CBL methodology will be complemented by agile methodologies for software development, the Belbin method for team building, and methodology design thinking with the lean methodology to ensure a comprehensive approach to learning and development.

The study will incorporate a personalised intelligent chatbot to support students in their development with the proposal. The chatbot will be designed to answer any questions regarding CBL, enabling students to understand better and utilise the methodology.

The materials and methods used in developing the application will be described in detail to achieve the study's objectives. This includes the respective concepts, user roles, user history, acceptance criteria, mockups, data design, components used, and tests.

Overall, the study aims to promote innovation and provide stakeholders with a platform to gain more experience and confidence to face the world of work. The study is significant in that it offers an innovative approach to learning that provides a bonding ecosystem for students and university graduates to put their knowledge into practice while also addressing the demands of the job market.

2 Related works

Since the beginning of the internet, it has been possible to establish new forms of learning that new generations of students prefer due to dynamism and flexibility. This is why consumption of online courses and programs is increasingly in demand (Song et al., 2004). In the same way, using learning methodologies with significantly better performance than traditional learning is becoming more frequent. Likewise, where

students apply their knowledge to real problems significantly impacts knowledge and soft skills.

Hu et al. (2018) implemented a web platform using CBL in the Java programming course. With this method, the practical capacity of the students was improved, as well as the capacity for innovation, and the results were favourable.

Roselli and Brophy (2006) compared traditional learning with CBL for three years. They concluded that they significantly performed more complex questions when using the CBL. In addition, the authors affirm that this learning has the potential to better prepare the student for work and throughout life. Similarly, Lo and Hew (2017) applied the flipped classroom approach, emphasising the importance of having a flipped class and generating challenges that allow students to learn. As a result, it achieved significant performance compared to learning in traditional classrooms.

Gaskins et al. (2015) identified high dropout rates of students in engineering institutions due to the traditional learning system they have implemented. That is why, to reduce negative experiences and increase motivation, CBL was introduced in an electronic circuit course; positive results were obtained due to improved classroom experience. Similarly, another investigation (Santos et al., 2015) implemented the CBL methodology with the Scrum methodology focused on mobile development learning. Thanks to both, favourable results were obtained in teaching; in the same way, learning was faster, concluding a successful integration.

Legaki et al. (2020) used gamification and CBL to increase student motivation, presenting an experience of 365 students from different engineering careers, demonstrating a positive impact. In robotics, it was also possible to apply CBL.

Due to the rapid development and evolution of the use of CBL, different projects have been chosen around the subject, among which are the following:

RoboSTEAM (Conde et al., 2019) is a project that applies the methodology based on challenges in the hands of a small robot and a web page where a small instruction manual is provided with templates on how the challenges should be created. The so-called RoboSTEAM aims to facilitate understanding the challenges and have an interactive way of approaching the students.

CBL applied to mobile software development teaching (Binder et al., 2017) was born with the need for training for the development of applications; this methodology was implemented for 110 students, and the student's results were analysed through thematic networks. Thanks to the success of the research, it was later proposed to implement it for different areas of learning.

Programming teaching based on network teaching platform: this teaching method was implemented through a web platform for students in the programming course for the Java programming language (Hu et al., 2018). The practical capacity of the students improved, in addition to the capacity for innovation, and their results were favourable.

Mathematical ability through challenge-based learning: the proposed mathematical challenges of Android applications for greater accessibility yielded good results so that the mathematical representation capacity was improved while the material was easily understandable. The case study was developed in Bandung (Susilawati, 2020) for 79 students, where they were implemented between experimental and control classes.

In this project (Santos et al., 2015), the CBL method was implemented with the Scrum methodology to improve teaching and education in teachers and students focused on mobile development. They were combining CBL and Scrum framework for mobile

application development. Both gave favourable results in teaching the students, the teaching method was faster, and both methodologies were successfully integrated.

Labour Rights is a mobile application that seeks to be a support tool for workers in developing countries in which they can make public all the incidents, deficiencies, negligence, and labour injustices they face that are part of the conventions of the International Labor Organization. To store their data, they use an API; when logging in, they use Laravel Sanctum to make requests that the role of the token allows. It has a lightweight authentication system for simple token-based APIs, allowing you to generate specific tokens according to your skills and giving you restricted access.

CBL physics and mathematics teachings: at the Technological University of Monterrey, an Educational Model called Tec21 (Santiago Acosta et al., 2018) was implemented, which promotes the use of challenges and activities for learning in students aimed at all careers; in this way, they divided the system into innovation week and semester of innovation and worked with the world's leading pharmaceutical company Boehringer Ingelheim for 14 weeks.

They were changing the learning environment in the College of Engineering and Applied Science using CBL. In engineering institutions in the USA, high dropout rates have been seen by students due to the learning system they have implemented.

That is why, to reduce negative experiences and increase motivation, CBL was introduced in an electronic circuits course (Gaskins et al., 2015). Due to this, there was an improvement in the classroom experience for students who followed this methodology.

3 Materials and methods

Scrum (Bolloju et al., 2018) is one of the best-known agile methodologies. One of its principles is to work with small work teams to maximise communication and reduce supervision, having greater adaptability to modifications. Among the advantages of its use, we have:

- it allows development teams to provide a quality product according to the needs of the client/user, ensuring time and money savings
- large projects can be streamlined into small tasks
- developers go hand in hand with testing
- all stakeholders gain high visibility of the project through the meetings
- it allows you to accept feedback much faster
- there is a better appreciation of each member's work and her progress.

This methodology was used considering the following considerations: It was possible to appreciate the transparency between the processes that the application has, and it helps to manage a better workflow while it is carried out as a team; for this reason, our priorities were divided into the realisation of each module that our application will have. Our first identified module was the user registration module; in this module, we propose registering participating users, users from research or entrepreneurship groups, universities, and institutes that will create the challenges. As already stated, the objective

of user registration is that this process is simple for the user, that is, that the data to be filled in is clear and precise and that this information arrives correctly in our database.

In Table 1, we can see a comparison of SCRUM against other known agile methodologies (Garcia et al., 2020).

Table 1 Comparison between SCRUM and other agile methodologies

SCRUM	*Other methodologies*
The most important thing is productivity to meet customer needs and to be flexible.	XP: Less flexibility, productivity is not as relevant. It seeks to increase value and quality.
It focuses more on effective communication between all stakeholders.	FDD: Less communication and more complex procedures, oriented to large development teams.
All actors participate in the development, and the results are functional quickly.	DSDM: Complexity in the procedures focuses on first defining the time and cost of the project.
Users throughout the easy-to-follow development define requirements.	Crystal: Less considerate of the requirements and difficult traceability.

The app's backlog was ordered by the priorities that were previously analysed:

1 define user roles

2 identify user stories

3 identify customer requirements

4 identify the modules the application will have about the requirements

5 make mockups of the application

6 define the database to use

7 develop the user registration module

8 develop the challenge creation module

9 develop the challenge participation module.

3.1 User roles

The development team consists of the people who deliver a potentially releasable Increment of the 'done' product at the end of each spring. The user roles were defined at the beginning of the project. They are the product owner who is the one in contact with the business work environment. The scrum master, who leads the scrum team and serves the organisation in general and as stakeholders and external clients, was identified, and the users would be students and universities.

3.2 User stories

For Sprint, the goal was to develop the user registration module. User stories about the roles identified to participate in this application were identified, as seen in Table 2.

Table 2 User stories

Story ID	*Role*	*Characteristic/functionality*	*Reason/result*	*Scenario number*
CE0001-0001	As an administrator	I need to allow participants to enter.	In order that they can use the application without a problem.	1 2
CE0001-0002	As a student	I need to enter my data.	To complete the registration of the platform.	1 2 3
CE0001-0003	As a university	I need to enter my data.	To complete the registration on the platform.	1
CE0001-0004	As an administrator	I need to keep a constant record of the challenges on the platform.	To have a follow-up of the growth of the use of the platform.	1 2 3
CE0001-0005	As a university	I need to publish my challenges.	To generate interest in a topic so that participating users come up with solutions.	1 2 3
CE0001-0006	As a student	I need to participate in creative challenges.	To strengthen my learned knowledge, I contribute a creative idea.	1 2 3
CE0001-0007	As a student	I need to know the active challenges.	To participate in one of my currently active interests.	1 2
CE0001-0008	As a student	I need to know the organisers of the challenges.	To participate in a challenge given by a university of my interest.	1 2

In Table 2, the first column has the history identifier, which allows visualising the following requirements. The role column refers to the user roles that have been identified to be participants. In characteristic/functionality, it represents the function the role wants or needs to do in the application. The reason/result column is what the role needs to accomplish by executing the action, or it can also be the result of executing the action from the role's point of view. Moreover, the scenario number is the number of requirements that will be needed from this usage history.

3.3 Criteria of acceptance

From this Sprint, it was possible to find the requirements and acceptance criteria for CBL during the daily stand-up, as seen in Table 3. In the first column is the ID of the user story that is being referenced as the acceptance criterion; in the second column, the title of the acceptance criterion describes the context of the scenario that defines behaviour, and the context provides a further description of the conditions that trigger the scenario. The event column represents the action the user executes in the context already defined for the user. The expected behaviour/result column is the system's behaviour. These

criteria also cover the negative parts of what will happen 'if', that is, what would happen if, for example, no related challenges are found when looking for a university.

Table 3 Criteria of acceptance for challenge-based learning

Story ID	*Acceptance criteria (title)*	*Context*	*Event*	*Expected result/behaviour*
CE0001-0004	Record of creation of training challenges.	In case users raise and publish new challenges.	When a user posts a new challenge.	The system will display a screen with the challenge creation date and who published it.
	Record of creation of entrepreneurship challenges.	In case users raise and publish new challenges.	When a user posts a new challenge.	The system will display a screen with the challenge creation date and who published it.
	Record of creation of academic challenges.	In case users raise and publish new challenges.	In case users raise and publish new challenges.	The system will display a screen with the challenge creation date and who published it.
CE0001-0005	Publication of the training challenge.	In case you want to give practice to student users to prepare them for the challenges	When the option to post a challenge is selected.	The system will display a form that needs to be filled out.
	Publication of the entrepreneurship challenge.	In case a creative solution to the current problem is sought.	When the option to post a challenge is selected.	The system will display a form that needs to be filled out.
	Publication of the academic challenge.	In case a creative solution to a current academic problem is sought.	When the option to post a challenge is selected.	The system will display a form that needs to be filled out.
CE0001-0006	Participate in the training challenge.	If you want to test the knowledge learned, train them before participating in another category of challenges.	When the option to participate in the challenge is selected.	The system will display an initial form that needs to be filled out.
	Participate in the entrepreneurship challenge.	If you want to test the knowledge learned, apply it in innovative solutions to the problem of the entrepreneurship challenge.	When the option to participate in the challenge is selected.	The system will display an initial form that needs to be filled out.
	Participate in the academic challenge.	If you want to test the knowledge learned, apply it to solve the problem of the academic challenge.	When the option to participate in the challenge is selected.	The system will display an initial form that needs to be filled out.

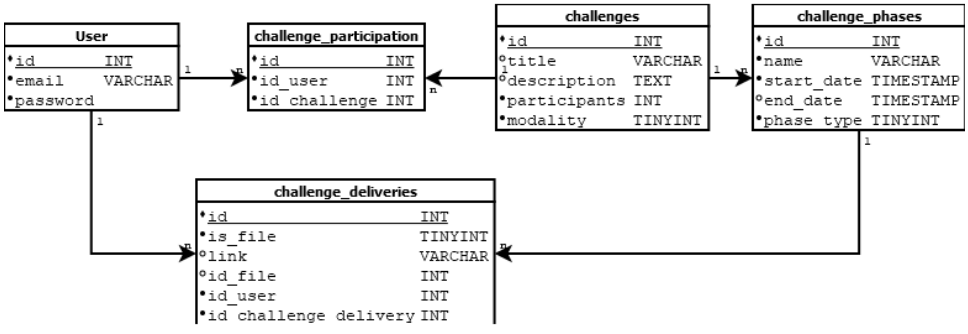
Table 3 Criteria of acceptance for challenge-based learning (continued)

Story ID	*Acceptance criteria (title)*	*Context*	*Event*	*Expected result/behaviour*
CE0001-0007	Look for active challenges.	If you want to participate in a challenge on specific recent or upcoming dates.	If you want to participate in a challenge on specific recent or upcoming dates.	The system will display a list of active challenges.
	An unsuccessful search for challenges.	In case no active challenges are found for the time the student user wishes.	When placed in the filter, the desired state of the challenges.	The system will display an empty page without displaying any challenges.
CE0001-0008	Search university challenges.	In case you want to participate in a challenge published by universities of interest to the student user.	The university from which the challenges are sought when placed in the filter.	The system will display a list of challenges published by the selected university.
	An unsuccessful search for challenges.	In case no challenges published by the university of interest are found.	In case no challenges published by the university of interest are found.	The system will display an empty page without displaying any challenges.

3.4 Data design

Creating data models is the initial and most crucial step. For this, the relational model for creating the database was initially made, and the DIA tool was used; this work can be seen in Figure 1 in short form (Link to the full version: https://bit.ly/3RziBAM)

Figure 1 Relational model



However, as it is part of the backend of the current project developed in a web environment, the mobile application uses the main ones, such as the user table and the challenges table.

3.5 App interfaces

The creation of the mockups was based on the priority of requirements. Figure 2 shows the generated views: login, registration, home, account, search, and challenges. The application logo can be seen in the login view; the user's email and password are requested to enter the application. After entering the Home view, the last challenges entered into the system are shown; below will be the categories: training, academic, and business. In the person's icon, you will find the Account view, which indicates the type of user, the user's name, and an account configuration area, where the request configuration options, change password, notifications, and deactivate account are located. You can search for one or more specific challenges based on their name in the Search view.

Figure 3 shows the CBL interfaces.

Figure 2 App home interfaces (see online version for colours)

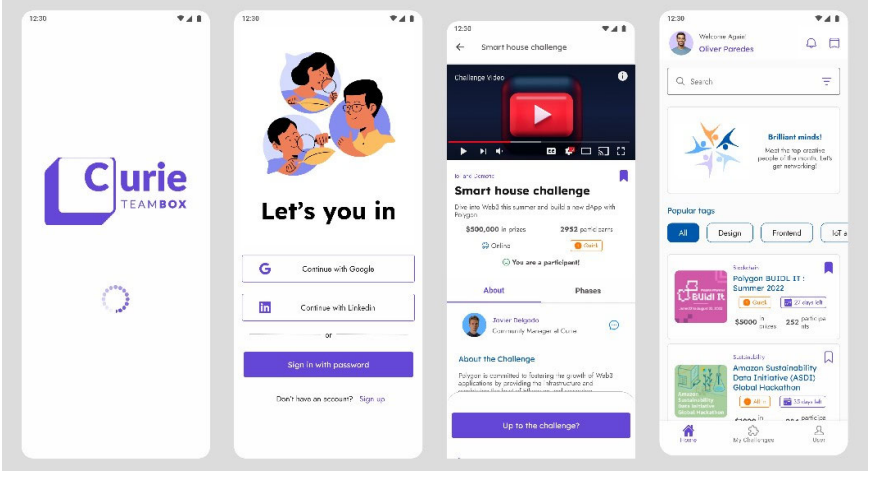
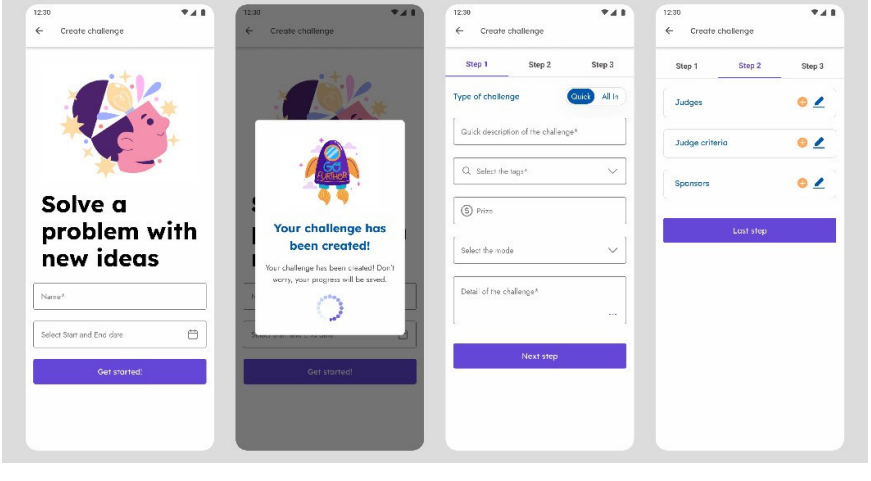


Figure 3 Challenge-based learning interfaces (see online version for colours)



3.6 Software development

The code used to carry out this project can be found in the following link to a GitHub repository to view it in better detail:

- https://github.com/alexander-acuna-ramirez/curie-movil.

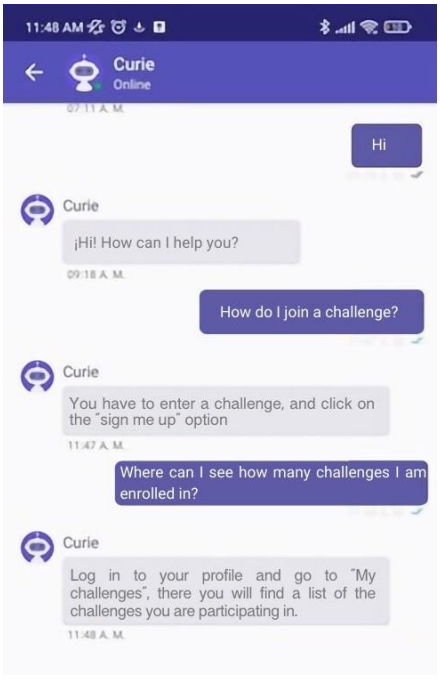
The application was developed considering the following tools:

- *Vue:* Vue.js (Novac et al., 2021) is an open-source model-view-view-model front-end JavaScript framework for building user interfaces and a web application framework for building single-page applications. The advantage of Vue.js is that it can be developed in components, significantly reducing the amount of code you write and making it easier for readers to understand.
- *Laravel:* its open-source framework aims to facilitate and speed up application development through its simple, expressive, and elegant syntax (Nugroho et al., 2019). It follows the model-view-controller (MVC) architectural pattern and combines the best of known web frameworks in other languages. It facilitates everyday tasks for most projects like authentication, routing, sessions, and caching and pretending to make the development process more enjoyable.
- *Laravel Sanctum:* Sanctum is a simple package to issue API tokens to your users without complicated OAuth (Seputra and Dewi, 2022). This feature was inspired by GitHub and other apps that issue 'personal access tokens'. Additionally, it provides an easy way to authenticate single page applications (SPAs) that need to communicate with APIs powered by Laravel; Sanctum, in this case, does not use tokens of any kind but instead uses cookie-based session authentication service Laravel's built-in, which offers the benefits of CSRF protection, session authentication.
- *MySQL:* MySQL (Axmark and Widenius, 2021) is a prevalent open-source database management system. It is recognised thanks to its simplicity, ease of understanding, and high performance. It is available for different platforms. It is developed in C/C++, and its API is available in various languages such as C, C++, Eiffel, Java, and PHP, among others. Additionally, its response speed is widely highlighted; it supports different storage methods, is highly reliable in terms of stability, and has a very high level of security.
- *Firebase:* Firebase is a set of real-time backend database services that help developers quickly write web and mobile applications. It was used for the messaging part (Albertengo et al., 2019) of the application since it allows messages and notifications to be sent to users on various platforms (Android, iOS, and web). Messages can be sent to individual devices, groups of devices, and users subscribed to specific topics or user segments.
- *Chatbot:* artificial intelligence (AI) and speech recognition have enabled chatbots (Skjuve et al., 2021) to interpret human natural language input and become more intelligent by continually learning from users' past experiences. This is achieved through natural language processing (NLP) and machine learning. Synchronous communication between these applications via API is now possible thanks to these

advances. The application implemented a chatbot to help users with their doubts, for which interactions included support, contact, and categories, among others. Figure 4 shows the interaction of the chatbot.

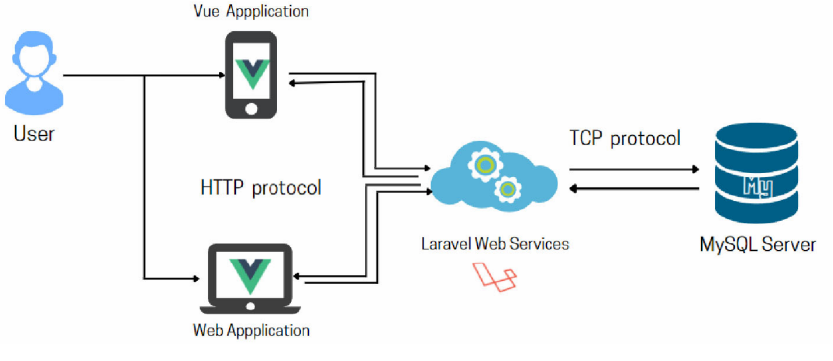
For the proposal, API was considered using Laravel as a framework and MySQL for data persistence; this API will be consumed by a web application made in Vue.js and a mobile application built using the same framework, which covers Android and IOS.

Figure 4 Interaction of the chatbot (see online version for colours)



Platforms: the use of these components resulted in architecture map seen in Figure 5. It starts with the user using either the mobile or web application.

Figure 5 Architecture map (see online version for colours)



3.7 Software testing

Functional test cases were performed for the testing phase, as well as performance and user interface tests. Table 4 shows the results obtained.

Table 4 Test cases for the app

Functional test cases	*Response*
Check if a user can log in with a valid username and password.	Positive
Check if a user cannot log in with a valid username and invalid password.	Positive
Check the login page for both when the field is blank and the Submit button is clicked.	Negative
Verify that the user can register and can access their account.	Positive
Check to view all the challenges.	Positive
Verify that the user can see the detail of a challenge.	Positive
Verify that the user can enrol in a challenge.	Positive
Verify that the user can search for a challenge.	Positive
Verify that the user can talk to the chatbot.	Positive
Check that the user has an understandable response and is understood by the chatbot.	Positive
Check the functionality of forgot my password.	Negative
Check for invalid login messages.	Positive
Check if a user can log in with a new password only after the password has been changed.	Positive
Check if the 'enter' key on the keyboard is working correctly on the login page.	Positive
Check the time it takes to connect with a valid username and password.	Positive
Verify that the data of each challenge are the corresponding ones.	Positive
Check the time it takes to connect with a valid username and password.	Positive
Check whether the login page's font, text colour, and colour coding conform to the standard.	Positive

4 Software testing

Following the recommendations of the Framework Scrum, the Sprint Review was carried out, which allowed the results of the Sprint to be inspected to determine future adaptations. In addition, using Brooke's system usability scale (SUS) instrument (Brooke, 1996), which made it possible to measure through the unique Likert scale of between 1 and 100 the usability and user experience of the CBL system, in which the questions shown in Figure 5 were included.

Taking into consideration that the maximum weighted value in the SUS test is 4 points for each question formulated and observing the resulting value of the intentional sample of 83 points average value as a measure of dispersion, it is evident that the indicators of the usability and user experience of the CBL exhibited a positive coefficient

concerning the evaluation of the app's functionalities by the university students, achieving the objectives of the research.

To evaluate the quality of the application, the international standard ISO/IEC 9126 (Al-Kilidar et al., 2005) was used, which arises from the need for a single model to express the quality of the application. This is presented according to the sub-characteristics: quality and use defined in ISO/IEC 9126-1.

Table 6 shows the results obtained, where the real value in the evaluation of quality in its different characteristics is 79 compared to the expected value, which is 77.

Figure 6 SUS test results (see online version for colours)

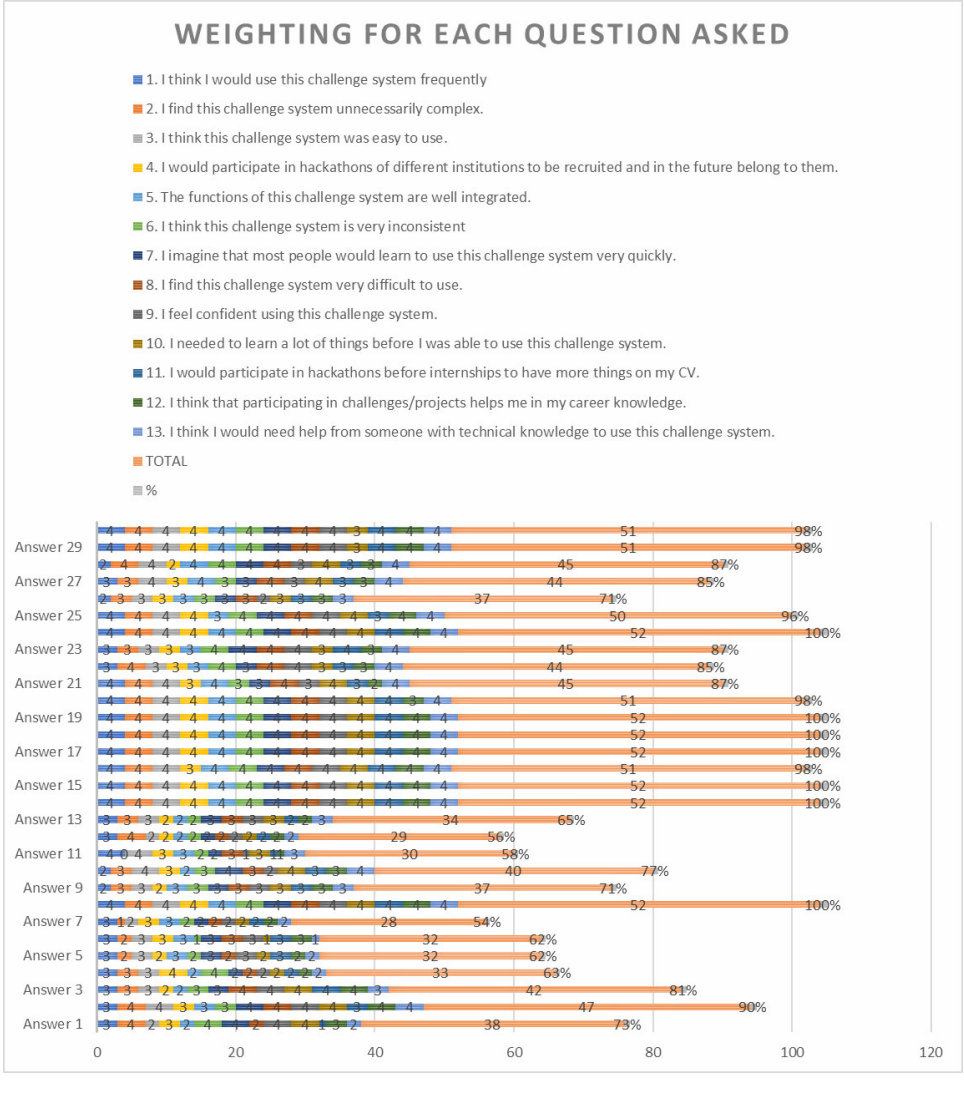


Table 5 Challenge-based learning quality results according to ISO/IEC 9126

E	*R*	*Characteristics*	*P*	*E*	*R*	*Sub characteristic*	*P*	*E*	*R*
0.77	0.79	Functionality	30.0	0.77	0.82	Applicability	30%	0.75	0.83
						Precision	10%	0.85	0.92
						Interoperability	20%	0.67	0.74
						Security	20%	0.72	0.75
						Functionality compliance	20%	0.89	0.92
		Reliability	25.0	0.79	0.79	Maturity	30%	0.82	0.86
						Fault tolerance	30%	0.74	0.76
						Recoverability	20%	0.77	0.80
						Reliability compliance	20%	0.82	0.74
		Usability	25.0	0.78	0.76	Understandability	20%	0.80	0.79
						Ease of learning	20%	0.86	0.82
						Operability	20%	0.72	0.75
						Attractiveness	20%	0.92	0.95
						Learning compliance	20%	0.60	0.50
		Efficiency	10.0	0.70	0.72	Behaviour over time	30%	0.64	0.70
						Use of resources	30%	0.71	0.70
						Efficiency compliance	40%	0.73	0.76
		Ease of maintenance	5.0	0.80	0.81	Analysability	15%	0.63	0.66
						Changeability	20%	0.74	0.71
						Stability	20%	0.80	0.82
						Testability	20%	0.87	0.88
						Ease of maintenance compliance	25%	0.91	0.93
		Portability	5.0	0.71	0.73	Adaptability	20%	0.72	0.73
						Installability	30%	0.71	0.74
						Co-existence	10%	0.64	0.66
						Replaceability	10%	0.62	0.60
						Portability	30%	0.75	0.78

5 Discussion and conclusions

Our results show that it was possible to develop a mobile application that integrates challenge-based learning with a chatbot to encourage innovation in university students in an acceptable way, which was validated in terms of usability with the Brooke SUS instrument in 83% and with the ISO 9126 software quality tests with a real value of 79.

These results are like those found by Rivas and Husein (2022), who points out that the principles of CBL are the primary candidate testing ground to integrate new forms of teaching. Likewise, Vázquez-Villegas et al. (2022) state that CBL was designed as a culturally relevant academic experience for college students. Also, the article by Félix-

Herrán et al. (2022) states that the rapid pace of technology and innovative knowledge encourages universities to employ CBL approaches in engineering education supported by modern technology.

Regarding the usability of the app, Bernal et al. (2022) state that the evaluation using the SUS showed marginally good usability, with opportunities for improvement and high acceptance in software development. This is related to what was expressed by Chung and Wu (2017), in which they recommend the combination of the SUS and the user interaction satisfaction questionnaire (QUIS) to validate learning software. As well as in the work of Ponte et al. (2019) shows that retrieval-based learning can be an adequate alternative in the use of mobile applications and can be medical with SUS.

This study represents a significant contribution to CBL for university students; however, a limitation found in the study was not having sufficient resources to have achieved more excellent coverage of activities dedicated to the subject of study, and although it was not the purpose of the study, it could have increased from the baseline on learning based on challenges in university students.

The most important contribution is to support university students in the practice of the knowledge obtained through real challenges, for which an application was developed that creates and promotes a bond between institutions, companies, and students.

As future work, it can be considered to increase the challenges in learning for other areas of interest that university students require.

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