Open Banking Model for Financial Inclusion in University Students with Biometric Authentication and Risk-Based Compliance

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August 15, 2023

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Abstract— **Access to financial services is crucial for full economic participation. However, many university students face limitations in accessing these services due to limited financial literacy and lack of knowledge about financial products. This article presents a solution for the limited financial inclusion among technical university students in Peru, utilizing an Open Banking model and biometric authentication to facilitate account opening and minimize entry barriers. We compare technologies, cloud platforms, and web applications in different regions where Open Banking has been implemented. We detail the proposed solution, including web application architectures and integration with a leading bank's public Application Programming Interface (API) in Peru, enabling bank account opening with facial biometric recognition and One-Time Password (OTP). The methodology for developing and evaluating the solution is described, with a focus on data collection and analysis. The results obtained, which exceeded 70% in all proposed categories such as satisfaction, accessibility, effectiveness, security, and usability, indicate a significant improvement in financial inclusion among university students. The article concludes that the proposed model contributes significantly to financial inclusion, as indicated by an average user satisfaction index of 77.20%.**

Keywords—: open banking, financial inclusion, biometric authentication, risk-based compliance, one-time password

I. INTRODUCTION

Financial services are necessary for economic participation. As indicated in [1], many university students struggle to use these services owing to their low financial education, unwillingness to take on debt, and lack of financial product understanding. 57.5% of Chilean university students lack financial education [2]. 70% of Saudi male university students lack financial education, stability, and security [3]. According to Indonesian study [4], personal finance education increases students' financial knowledge, attitudes, and behavior.

The problem of limited financial inclusion among university students can have significant consequences, including limiting their participation in the economy and potentially impacting their academic success and overall well-being [5]. According to research in India and Turkey, financial literacy, which encompasses financial knowledge, attitude, and behavior, is a crucial factor in accessing financial services [6,

7]. The development of financial literacy can be supported by university financial education programs, banking experience, and parental socialization, and it is particularly beneficial for students from vulnerable economic backgrounds [8]. Financial knowledge helps students manage their finances and improve their well-being [7, 8]. Financial knowledge is vital for SME success and national financial inclusion, both individually and professionally [8]. Therefore, it is essential for university students to graduate with financial literacy to secure future income and higher savings rates [8].

The selected studies provide diverse perspectives on financial inclusion and fintech. Study [22] emphasizes the importance of regulation in the fintech sector and how it can impact market disruption. In the Latin American context, study [23] highlights the role of fintech in financial inclusion and access to financing in Brazil. [26] examines how fintech creates value for customers, a crucial aspect for our proposal that seeks to generate value for university students in Peru. Finally, [32] addresses the relationship between fintech adoption and financial inclusion, offering insight into how consumers adopt these technologies, which is essential to understanding how Peruvian university students can adopt our proposed solution.

Open Banking and similar technologies have been studied for financial inclusion and access. Financial literacy is a major barrier to financial inclusion [1]. Researchers have examined blockchain technology and robust access control measures to improve Open Banking security and privacy [9].

Unlike study [22], which emphasizes financial regulation in the UK and Germany, our project focuses on implementing cutting-edge technologies like Open Banking for Peruvian students, biometric facial recognition, and OTP security. In contrast to study [23], which focuses on access to financing in Brazil, we propose a university web platform that facilitates access to financial services and promotes financial education in Peru.

Furthermore, the proposed model offers a distinct approach compared to previous studies. In contrast to [9], which proposes a blockchain-based access control scheme for Open Banking security, our project focuses on the financial inclusion of Peruvian students through technologies such as biometric facial recognition and OTP security. Additionally, unlike [10], which emphasizes the implementation of a

specific security architecture to protect data in Open Banking, our project goes beyond security, seeking to promote financial education and provide easier and safer access to financial services through a university web platform.

Our proposal differentiates itself from the mentioned alternatives in that it not only addresses the limited financial inclusion of university students in Peru by providing them with a secure and convenient way to open bank accounts and access a wide range of financial services through redirection from the university web platform, but also aims to foster education and financial literacy among students. Additionally, our solution utilizes a combination of cutting-edge technologies such as Open Banking, biometric facial recognition, and OTP security to provide an easy and secure user experience for students. By utilizing the staging of the mentioned bank's public API, our solution enables students to remotely open bank accounts, eliminating the need to visit bank branches, thus reducing entry barriers, and increasing accessibility to financial services for university students.

We propose an Open Banking solution that integrates the staging of the mentioned bank's public API for bank account opening with a biometric facial recognition solution and OTP security for student authentication. The solution will be implemented as a web application using technologies such as NodeJS, React, ExpressJS, MongoDB Atlas, and an Azure cloud platform. Our solution will enable students to remotely open bank accounts without visiting bank branches and access a variety of financial services.

Article structure: Section 2 details the proposed Open Banking solution, including system architecture, API integration, and biometric authentication. Section 3 details the solution development and testing methods, including data collecting and analysis. Section 4 presents the study's results, including system performance, user feedback, and impact on financial inclusion among university students. Finally, Section 5 concludes the article with a discussion of the study's implications, limitations, and future research directions.

II. Related Works

This study aims to investigate the potential of a web application based on Open Banking for the financial inclusion of technical and university education students. A comprehensive literature review was conducted on 27 scientific articles obtained from reputable databases such as Scopus, Web of Science, and IEEE Xplore. Key parameters such as "Open API in financial sector," "Open Data in financial sector," "Open Banking," "Open Banking for financial inclusion on college students," "Financial inclusion on college students," and "Financial literacy on college students" were used to identify relevant articles. The quality of these articles was verified using the "Scimago Journal" platform, selecting only those published in "Q1" or "Q2" quartile journals and no older than 3 years. The results were categorized into four topics: "Technological solutions for financial inclusion," "Open data and public APIs," "Limited financial inclusion and financial education for technical and university education students," and "Impact of Open Banking and technology on financial inclusion," which frame the main findings and recommendations of this research. Table 1

displays these categories along with the respective categorized scientific articles.

Category	Paper
Technological solutions for financial inclusion	10, 11
Open data and public APIs	12, 13, 14
Limited financial inclusion and financial education for technical and university education students	15, 16, 17, 18, 19, 20, 21
Impact of Open Banking and technology on financial inclusion	22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36

Table 1. Categories of related works

Comparing supplementary efforts to the primary project:

Financial inclusion studies [10] and [11] emphasize technology. [10] examines the variables affecting mobile banking uptake in Bangladesh, whereas [11] examines fintech's influence on financial inclusion in Southeast Asia. These papers explain how technology solutions might promote credit and financial inclusivity.

Open data and public APIs dominate [12–14]. These studies examine how APIs and open data might improve financial inclusion and credit access, laying the groundwork for fintech solution development.

There is a deficiency in financial inclusion and financial education among technical and university students, as shown by sources [15–21]. The magazines aim to educate college students about money management and foster a more welcoming environment on campus. The chance of college students getting authorized for credit and participating in the financial mainstream is lower for those who lack financial literacy.

The implementation of digital technologies, the creation of financial education programs, and the encouragement of student engagement in financial activities are just a few of the strategies and solutions investigated in studies like [15], [16], and [19]. Our research hopes these tactics and ideas will help college students secure credit and other financial resources.

The topic of financial inclusion has been examined in scholarly works such as those referenced in citations [22]-[36]. Open Banking and financial technology affect loan availability and financial inclusion, and these papers provide many perspectives on these topics. Both [22] and [23] investigate the impact of Open Banking on financial inclusion in India and the possibility that it would enhance loan availability in Jordan.

Some of these studies also examine how blockchain and artificial intelligence might be used in Open Banking solutions to improve financial inclusion and credit availability. [34] and [35] examine blockchain technology and artificial intelligence in the banking industry, respectively.

These studies provide a diverse and comprehensive overview of how financial technologies, and the Open Banking model can improve financial inclusion and access to credit, which can help us develop our research and solutions.

III. CONTRIBUTION

A. Context

The advancement of Open Banking, coupled with facial recognition and OTP implementation, has revolutionized the process of opening bank accounts by providing robust security and an enhanced customer experience. Facial recognition, utilizing advanced algorithms, verifies identity, eliminating the dependence on potentially falsifiable physical documents, thus minimizing the risk of identity theft and related frauds [37]. Furthermore, the implementation of One-Time Password (OTP) serves to verify that the user possesses the registered device, thereby augmenting the security measures against illicit entry, as emphasized in reference [38].

The proposed model also improves the customer experience by simplifying the account opening process, allowing them to complete it from their personal device without the need to visit a bank branch, optimizing response times, and increasing customer satisfaction. Open Banking, facilitating secure data sharing through APIs, establishes a collaborative ecosystem that fosters innovation and efficiency. In summary, Open Banking, along with facial recognition and OTP, offers a balance of security and convenience, bolstering trust in the financial sector and paving the way for future innovations.

Therefore, a model of Open Banking based on facial biometrics and the Risk-Based Compliance method is proposed for the management of bank account opening in university and technical education institutions. This method aligns with current compliance management, which, according to [39], utilizes a risk-based approach based on international standards, principles, and organizational culture. In the context of our model, it is used to identify and mitigate the most relevant security risks, such as identity theft or financial fraud. As depicted in Figure 1, the proposed model consists of two modules: student and administrator, incorporating a set of security features to ensure confidentiality, integrity, and availability of information, following the philosophy of focusing compliance measures on areas of highest risk.

The student module encompasses the functionality for opening a bank account through a secure web service. This service employs Multi-Factor Authentication (MFA), including facial biometrics and OTP, to ensure that only authorized users can access the system. Data in transit and at rest are protected using robust encryption protocols like Transport Layer Security (TLS), preventing interception or theft of information. Additionally, access token management is implemented to control access to APIs and services.

The information system supporting the Open Banking model consumes the web service for bank account opening, thus establishing the necessary authentication security that the bank requires. This system also implements Role-Based Access Control (RBAC) to ensure that each user has access only to the information and functionality necessary for their role.

This model considers stakeholders such as the bank, university, students, and administrators. Furthermore, in line with the Open Banking framework, this model implements proper data consent management, ensuring that users can give and withdraw their consent for the use of their data. This model and its components are depicted in Figure 1.
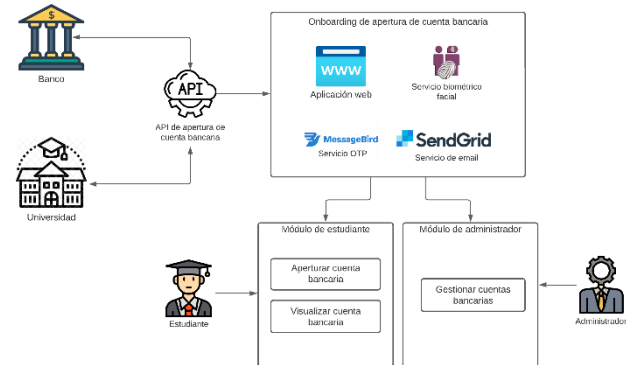

Figure 1. Open Banking Model based on Facial Biometrics and Risk-Based Compliance

The proposed Open Banking model focuses on integrating the bank's account opening process with the university's platform. It is supported by a web application and a set of strategically selected services, including the facial biometric service from the National Registry of Identification and Civil Status (RENIEC), the OTP service provided by MessageBird, and the email service from SendGrid. These components are effectively intertwined to streamline and expedite the bank account opening process, ensuring accurate authentication and seamless communication throughout the entire operation chain.

Within the model, the student module allows students to perform actions related to bank accounts. Students have the option to utilize the "Bank Account Opening" functionality to request the opening of an account. Additionally, this module offers the ability to "View Bank Account," enabling students to access and obtain relevant information about their existing accounts. These functionalities aim to provide an integrated and accessible banking experience within the university's educational environment.

Furthermore, the model includes an administrator module designed for efficient management of bank accounts. Administrative staff can perform tasks related to "Bank Account Management," including control and supervision of accounts in the system, permission configuration, user management, and general platform maintenance. Through this module, the goal is to ensure an adequate level of control and security in the Open Banking environment, allowing the university to efficiently manage student bank accounts and ensure a secure experience for all users.

Finally, the integration of these modules aims to provide students and administrative staff with a comprehensive

solution for bank account management. By leveraging collaboration with the bank and the educational platform, the proposed Open Banking model aspires to improve the efficiency and accessibility of banking services while promoting financial inclusion in the educational realm.

B. Method

A web application implementing the Open Banking Model based on Biometrics and Risk-Based Compliance is presented. The architecture of our application consists of a combination of services, a database, and APIs that allow for biometric authentication of users, meeting security requirements. This architecture provides users with access to financial services, such as bank account opening, transfers, and payments, ensuring a secure and reliable experience, as illustrated in Figure 2.
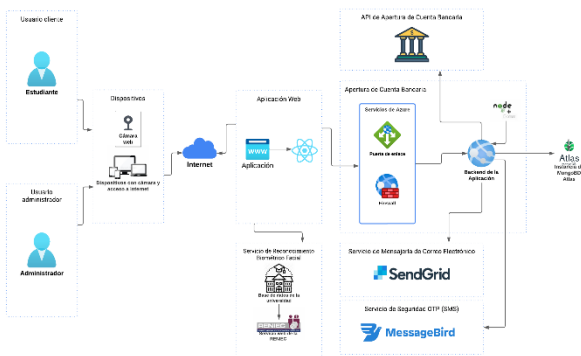

Figure 2. Technological architecture of the web application

Our system is utilized by two distinct groups of individuals, namely students and faculty. The web-based application enables students to create bank accounts and access their transaction records from any internet-enabled device, including but not limited to laptops, desktop computers, smartphones, and tablets. Notwithstanding, administrators possess additional functionalities and can manage student financial accounts and other administrative duties through the employment of identical devices as ordinary users.

An online connection allows for interaction between users and the program. Azure, a cloud services platform, hosts a web app with an easy-to-navigate UI that streamlines the user experience. The Node.js and Express.js-based application backend provides the business logic and interacts with the necessary external services.

A crucial component in our architecture is the facial biometric recognition service. This service, backed by a RENIEC database, verifies the users' identity through facial recognition to ensure accurate authentication.

At the core of this architecture is the security of the main process. This process is managed in a robust security layer, with Azure services like Gateway and Firewall, ensuring protection of access.

To store application data, MongoDB Atlas, a cloud-based database instance, is used. This database is essential for the functioning of the system, hosting relevant information for various operations.

The system also integrates with the email messaging service SendGrid, and the OTP (One Time Password) SMS security service provided by MessageBird. SendGrid is used for sending email communications to users, while MessageBird provides an additional layer of security by sending unique verification codes via SMS.

Lastly, there is an Open Banking account opening API layer that acts as an intermediary between our application and the bank, facilitating the opening of accounts and other necessary operations. This sophisticated and secure system architecture facilitates a secure, efficient, and user-centric banking experience.

IV. Experiments

A. Experimental Protocol

The present research advances an Open Banking framework for the administration of bank account initiation in higher education institutions, corroborated by experts in the financial sector and students from the designated university. The research utilized an empirical methodology by distributing three distinct questionnaires to both student and expert participants. The responses of the participants were assessed through employment of a five-point Likert scale that spanned the complete range of their perspectives, varying from "Strongly Disagree" to "Strongly Agree." The formula utilized for calculating the satisfaction index was as follows:

$$Satisfaction\ Index = (Number\ of\ positive\ responses\ /\ Total\ number\ of\ responses) * 100\%$$

In this equation, positive responses were considered those that scored 4 or 5, indicating that the user agreed or strongly agreed with the presented statement.

Furthermore, the quantitative objective of the surveys was to achieve a satisfaction index of 70% or higher. The questionnaires, implemented through "Google Forms," allowed for the collection and analysis of responses to achieve this objective.

To compare user experiences, a 10-question control questionnaire was given to 20 students, 10 of whom had used the online application and 10 who had not. Another 20 students completed the Digital Financial Inclusion Evaluation Questionnaire. The World Bank's Global Findex Database inspired this questionnaire, which examined user happiness, usability, efficacy, accessibility, and security [40]. This approach provides a complete evaluation of the proposed web application's quality and efficacy. Finally, three financial specialists completed a 30-question Nielsen-based questionnaire to assess user experience. These Jakob Nielsen criteria drive user interface design and assess system consistency and error avoidance [41].

Experiment 1 involved the formation of a control group comprising 20 students from the designated university, which was further subdivided into two groups of 10. The initial cohort was subjected to the purported instantaneous online platform for initiating bank account creation, while being

monitored by one of the contributors to the project. In contrast, the second group was directed towards the conventional method of opening accounts through the bank's website. Both groups responded to a control questionnaire designed to collect initial data and compare the students' experiences with both procedures.

Each student provided their signature on an Informed Consent Form, which precisely detailed the aspects related to their participation in the study.

The participating students received this questionnaire inquired about aspects such as ease of use in [42], process clarity as mentioned in [41], system speed, and overall satisfaction with the experience in [43]. This approach allowed valuable information to be collected to evaluate whether the new Open Banking web solution could fulfill its objective of facilitating the opening of bank accounts for university students. The selected questions in the questionnaire were designed to reflect the user experience from multiple perspectives. The questions asked can be found in the following link: https://docs.google.com/forms/d/1dqcaVegaXbB06cDBrXOmf24OCBixePAssHGNryo0NZM/prefill

Later, in Experiment 2, the second group of students who initially used the traditional method were invited to try the proposed web application. A survey designed by the Alliance for Financial Inclusion (AFI) was implemented to measure user satisfaction, usability, effectiveness, accessibility, and security of the proposed solution. The collected data allowed for an evaluation of the quality and effectiveness of the Open Banking solution.

The experiment protocol started with the selection of a sample, a group of 20 students from different faculties signed an Informed Consent Document detailing their participation in the study.

Before completing the questionnaires, each student will use the web-based application while being supervised by one of the project authors. The initial step is to use the student's code/email and the corresponding password to access the login. By accessing the system, the user will be able to choose a financial institution, select and view the details of the chosen savings account, as shown in Figures 3 and 4.
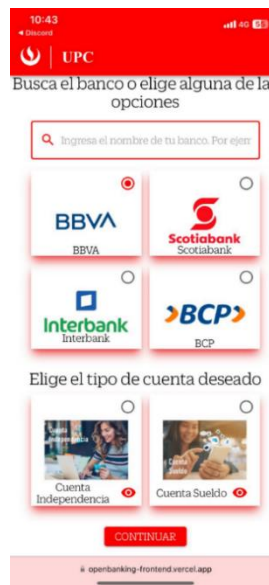

Figure 3. Bank Selection Screen Figure   4. Account Information Screen

Figures 5a and 5b show students completing the form after choosing a bank and account type. This form needs bank account opening information. Students must also accept each account option's terms and legal declarations.

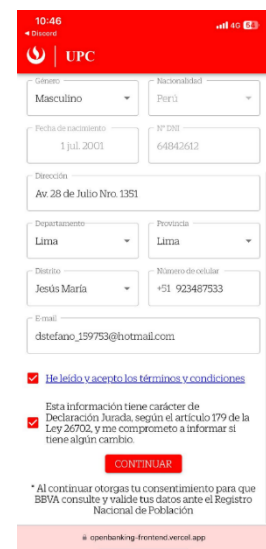**Figure 5a. Form Screen   Figure 5b. Form Screen**

Facial biometric recognition follows form completion. The student receives extensive instructions and advice for this procedure. Figures 6a and 6b demonstrate these guidelines.
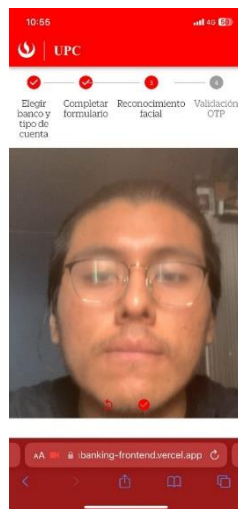
Figure 6a. Facial Biometric Screen

Figure 6b. Facial Biometric Screen

Figures 7 and 8 show that a final authentication process must be performed. The student must provide a One-Time Password (OTP) code, which will be sent to their mobile phone number from registration.

Figure 7. SMS Message for OTP

Figure 8. OTP Screen

The learner will see an interface confirming their bank account creation after each step. With this new bank account, the student may manage their accounts and establish new ones via the main system panel. Users may also view their financial data, including their student ID and bank account number. Figures 9 and 10 show the data.

Figure 9. Successful Opening Screen

Figure 10. Account Management Screen

After opening the new bank account and using all the main interface's functions, the students completed the Digital Financial Inclusion Evaluation Questionnaire, which assesses satisfaction with the account opening process, the web platform's usability, its effectiveness in promoting financial inclusion, its accessibility, and the security of personal and financial data. Technology may boost financial inclusivity. The selected questions with their respective dimensions are in the following link: https://docs.google.com/forms/d/13mVhrb4aYbJE3M2Tyh ZK4u0A66Kcv7hzut53yJmNizU/prefill

Experiment 3 involved an evaluation of the Open Banking web solution conducted by three experts in the financial sector, who assessed the user experience, system consistency, and error prevention, among other aspects. This experiment was based on Nielsen's principles to ensure an optimal user experience.

The experts received a well-crafted Nielsen-aligned questionnaire. System status visibility, consistency and standards, error avoidance, adaptability and efficiency, and user interaction and experience were examined. This method assessed whether the Open Banking online service achieved financial inclusion for university students. The selected questions aligned with the respective principles are in the following link: https://docs.google.com/forms/d/1059_kA1omDaI7JXQyLE 22Ysttu1aB8K03MHY84sv3r0/prefill

B. Results

The collection of responses from Experiment 1's students to the control questionnaire was visualized in two separate tables, each representing a group of students, those who used the proposed web application and those who opted for the conventional procedure through the bank's website. The question identifiers (P) were arranged on the vertical axis, while the student identifiers (U) were aligned on the horizontal axis.

ID	U001	U002	U003	U004	U005	U006	U007	U008	U009	U010
P01	5	3	5	3	5	5	4	4	5	5
P02	3	4	3	5	4	4	5	3	5	3
P03	4	4	4	4	3	5	4	4	5	4
P04	3	5	3	3	3	4	4	3	4	3
P05	4	3	3	5	3	4	3	5	5	3
P06	3	3	3	3	3	4	3	4	4	4
P07	3	3	3	4	4	3	4	3	3	4
P08	5	4	4	3	5	3	4	5	5	4

P09	3	3	5	4	4	3	3	3	4	5
P10	3	4	5	4	5	4	4	5	5	4
Total	3.600	3.600	3.800	3.800	3.900	3.800	3.900	3.800	4.500	3.900
%	72.00%	72.00%	76.00%	76.00%	78.00%	76.00%	78.00%	76.00%	90.00%	78.00%
										77.20%

Table 2. Results obtained with the group that used the web application

According to Table 2, the analysis of responses from the group that used the proposed web application reflected an outstanding satisfaction score of 77.20%. This result greatly exceeded the initial target of 70% for the satisfaction index, demonstrating an extremely positive evaluation regarding the user experience provided by our application. This high approval rate from the students suggests that the proposed web application greatly facilitates the process of opening bank accounts, optimizing its efficiency and accessibility.

ID	U011	U012	U013	U014	U015	U016	U017	U018	U019	U020
P01	3	2	1	2	3	2	3	1	2	1
P02	2	1	2	3	3	1	2	2	2	1
P03	3	2	1	3	1	1	3	3	2	2
P04	2	3	2	1	1	1	2	2	1	2
P05	1	3	1	2	2	2	1	1	2	2
P06	1	1	2	2	1	1	3	1	1	1
P07	2	1	1	3	3	2	1	1	3	1
P08	2	2	1	1	2	3	1	3	1	3
P09	1	3	2	2	3	3	1	1	3	3
P10	2	1	3	3	2	2	3	1	2	3
Total	1.900	1.900	1.600	2.200	2.100	1.800	2.000	1.600	1.900	1.900
%	38.00%	38.00%	32.00%	44.00%	42.00%	36.00%	40.00%	32.00%	38.00%	38.00%
										37.80%

Table 3. Results obtained with the group that did not use the web application

On the other hand, as shown in Table 3, the control group that used the conventional method of opening accounts through the bank's website obtained a considerably lower satisfaction score of 37.80% as the satisfaction index. This contrast, although surprising, demonstrates that the method that was previously considered the standard option may not be the most effective or satisfactory option for students in terms of a more personalized user experience.

In presenting the results of Experiment 2, a matrix was used in which the students' codes (U) were aligned on the vertical axis, while the five evaluated dimensions were arranged on the horizontal axis. Each dimension, in turn, was evaluated through four questions, although Table 4 presents only the average scores of the responses.

	Satisfaction	Usability	Effectiveness	Accessibility	Security
U001	3.50	3.50	3.75	3.75	3.50
U002	4.25	3.75	4.00	4.25	3.50
U003	4.00	3.50	3.75	4.25	3.50
U004	4.25	3.50	4.50	3.50	3.75
U005	3.50	3.25	3.75	4.00	4.50
U006	4.25	4.75	4.00	4.00	3.75
U007	3.50	4.00	4.25	4.00	3.75
U008	3.50	3.75	4.50	4.50	4.00
U009	3.50	4.75	4.00	3.75	4.00
U010	4.00	4.00	4.00	4.25	4.00
U011	4.25	4.25	3.25	4.25	3.75
U012	4.25	4.00	3.50	4.25	3.75
U013	3.00	4.25	4.00	3.75	3.25
U014	3.50	3.50	4.25	4.25	4.00
U015	4.50	3.75	4.00	4.00	4.00
U016	4.25	3.50	4.25	4.50	3.50
U017	4.00	3.75	3.25	4.50	4.00
U018	4.25	3.25	3.75	4.00	3.75
U019	3.75	4.50	4.00	4.25	4.25
U020	3.75	3.50	4.25	4.00	4.00

TOTAL	3.89	3.85	3.95	4.10	3.83
%	77.75%	77.00%	79.00%	82.00%	76.50%

Table 4. Results obtained from the student survey

The estimated satisfaction index for each dimension exceeded our 70% objective, as shown in Table 4. Satisfaction was 77.75%, showing student satisfaction with the planned online application. Students gave usability a 77% grade, indicating that it was simple to use. The application accomplished its goals and satisfied students' requirements with a 79% effectiveness grade. However, the Accessibility dimension scored 82%, showing that students found the software beneficial for creating bank accounts. Finally, security, a vital feature in banking, received a 76.50% rating, indicating great confidence in the proposed online application's security.

The results from the Experiment 3 survey, which utilized a questionnaire based on Nielsen's ten principles for user experience evaluation, reveal significant and valuable insights from experts in the financial sector. Table 8 presents a matrix aligning the identifiers of the experts (E) on the horizontal axis and Nielsen's ten principles on the vertical axis. Each principle was evaluated through three questions, although the table only displays the average scores of the responses.

	E001	E002	E003	TOTAL	%
Visibility of system status	4.67	5.00	5.00	4.89	97.78%
Match between system and the real world	4.33	4.67	4.33	4.44	88.89%
User control and freedom	4.33	4.67	4.67	4.56	91.11%
Consistency and standards	5.00	5.00	5.00	5.00	100.00%
Error prevention	4.00	4.00	5.00	4.33	86.67%
Flexibility and efficiency of use	5.00	5.00	5.00	5.00	100.00%
Aesthetic and minimalist design	4.67	5.00	5.00	4.89	97.78%
Help users recover from errors	4.67	4.67	5.00	4.78	95.56%
Help and documentation	3.67	4.67	5.00	4.44	88.89%
User interaction and user experience	5.00	5.00	5.00	5.00	100.00%

Table 5. Results obtained from the expert survey

Table 5 shows that each principle's satisfaction index was extremely favorable for the suggested system. "Match between system and real world" received a 97.78% grade, suggesting that experts thought the system provided enough information. "User control and freedom" scored 91.11%, indicating that users have strong control over their system interactions. "Aesthetic and minimalist design" scored 97.78%, suggesting that experts liked the system's clean, distraction-free design. "Error prevention" and "Flexibility and efficiency of use" scored 86.67%, proving the system prevents errors and streamlines activities. "Help users recover from errors" with 95.56% and "User interaction and user experience" got 100%, meaning that the system supports error recovery and delivers a great user experience. "Help and documentation" scored 88.89%, suggesting that the system delivers relevant and easy-to-access assistance.

C. Discussion

The three trials strongly validate the suggested online application for university bank account opening. Experiment 1 shows that the application improves user experience compared to the traditional way, as seen by the satisfaction ratings. However, Experiment 2 reveals exceptionally strong student assessments across all financial inclusion parameters, demonstrating the application's potential to improve university financial inclusion. Experiment 3, which assessed financial professionals, showed the application's strong design quality, with high Nielsen ratings in all areas. These data confirm that the suggested online application may improve university bank account opening administration.

The relevance of digital technologies in financial inclusion and user experience within the university education field is also evident. The proposed web application, based on an innovative Open Banking model with an API for bank account opening, facial recognition, and OTP, has proven to be notably superior in terms of usability and user experience, achieving a satisfaction index of 77.20% among the students who used it, compared to the 37.80% obtained by the conventional method, as evidenced in Experiment 1.

When evaluating financial inclusion (Experiment 2), students gave high ratings to all evaluated dimensions, including Satisfaction (77.75%), Usability (77%), Effectiveness (79%), Accessibility (82%), and Security (76.50%), surpassing the 70% target set in our study. These findings are consistent with [44], which emphasizes the importance of digital solutions in improving financial inclusion.

Furthermore, experts in the financial sector evaluated our system using Nielsen's principles (Experiment 3), obtaining higher average satisfaction index ratings of 80% in all principles, reflecting their approval of the effectiveness and design of our system. It is crucial to acknowledge that the findings are constrained within the confines of a particular academic institution. Consequently, conducting additional research in diverse settings is imperative to enhance the validity and applicability of our results.

V. CONCLUSIONS AND PERSPECTIVES

This study concludes that the developed web application, based on an Open Banking model, significantly contributes to financial inclusion among university and technical students in Peru. The results of the three conducted experiments demonstrated acceptance rates above 70% in all evaluated aspects, reflecting an improved user experience and a significant enhancement in terms of satisfaction, effectiveness, accessibility, usability, and security.

Our contribution lies in the innovative fusion of emerging technologies to promote financial inclusion. By combining the implementation of an Open Banking API with biometric facial recognition and OTP in an intuitive and secure platform, we not only eliminate barriers to accessing financial services but also foster financial education among students. Therefore, our proposal represents a significant leap in the approach to financial inclusion in the university context.

In terms of methodology, a web application was developed using technologies such as NodeJS, React, ExpressJS, MongoDB Atlas, and an Azure cloud platform. The effective integration of these technological components with the Open Banking API, biometric facial recognition solution, and OTP security allowed for simplifying and expediting the bank account opening process, ensuring precise authentication and seamless communication throughout the entire operation chain.

The validation of our proposal was carried out through the execution of three experiments that measured aspects such as satisfaction, effectiveness, accessibility, usability, and security of the application. The results evidenced an average acceptance rate of 77.20% of the application by users and the effectiveness of the proposal in improving financial inclusion among university students.

However, acknowledging the changing dynamics of the technological and financial environment, the need for future research work to enhance and expand the application's functionalities is evident. These could include the incorporation of additional financial services, personalization based on user needs and preferences, and the implementation of machine learning mechanisms for financial behavior analysis and the delivery of personalized financial advice.

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