Online-Journals.org

iJIM International Journal of Interactive Mobile Technologies

iJIM | eISSN: 1865-7923 | Vol. 17 No. 16 (2023) | OPEN ACCESS

https://doi.org/10.3991/ijim.v17i16.39523

PAPER

A Mobile Application Prototype Designed to Support Physical Therapy Assessment Learning Processes

Carlos Andrés Tavera Romero[1](✉), Jennifer Jaramillo Losada[2], María Fernanda Díaz Velásquez[3], Andrés Gerardo Domínguez Pineda[1], Victor Manuel Hurtado López[1]

[1]COMBA R&D Research Group, Faculty of Engineering, Universidad Santiago de Cali, Santiago de Cali, Colombia

[2]Health and Movement Research Group, Faculty of Health, Universidad Santiago de Cali, Santiago de Cali, Colombia

[3]GIEIAM Research Group, Faculty of Engineering, Universidad Santiago de Cali, Santiago de Cali, Colombia

carlos.tavera00@usc.edu.co

ABSTRACT

The present work is the result of applied research, which describes how the physical therapy program at the Universidad Santiago de Cali approached the support of the learning processes from the Guide to Physical Therapist Practice issued by the American Physical Therapy Association (APTA) from a teaching perspective using information technologies with an emphasis on mobile devices (D-Learning). The implementation process was conducted using the PSP (Personal Software Process) methodology, condensing its six characteristic moments to address the problem in four stages: planning, design, development, and validation, corresponding to phases 2 and 3 of the interdisciplinary project developed by and between the Schools of Engineering and Health Sciences, thereby understanding that the remaining phases exceed the scope of this paper (these phases include a systematic review, an analysis, and feedback from the academic community). A preliminary assessment describes the knowledge gathering and idea conception processes, as well as the solution design process in Enterprise Architect. Subsequently, the prototype was implemented, the corresponding documentation was prepared, and its usability was validated by the academic community at the university. Therefore, a supporting tool was generated, focusing specifically on learning about the Guide to Physical Therapist Practice.

KEYWORDS

software engineering, guide to physical therapist practice, testing, healthcare technology, mobile learning, teaching tools, interdisciplinary

1 INTRODUCTION

1.1 Theoretical framework

Nowadays, mobile devices are ubiquitous in many aspects of daily life [1–2], from personalized sports trainers to remote patient healthcare, or telemedicine (TM),

Tavera Romero, C.A., Losada, J.J., Díaz Velásquez, M.F., Domínguez Pineda, A.G., Hurtado López, V.M. (2023). A Mobile Application Prototype Designed to Support Physical Therapy Assessment Learning Processes. *International Journal of Interactive Mobile Technologies (iJIM)*, 17(16), pp. 95–115. https://doi.org/10.3991/ijim.v17i16.39523

Article submitted 2023-03-11. Resubmitted 2023-06-16. Final acceptance 2023-06-16. Final version published as submitted by the authors.

© 2023 by the authors of this article. Published under CC-BY.

which reduces the risk of exposure for patients and healthcare workers (which has been especially noticeable during the COVID-19 pandemic) [3].

The Covid 19 pandemic had generated an increase in the use of the Internet in school environments. The use of information technologies can support management processes [4] and training through digital tools such as interactive platforms [5–6] and mobile applications when is used as educational tools at all ages and levels of formal education [7–9].

Since mobile devices are constantly being updated and their market participation becomes increasingly strong, more and more functions are becoming available to the user community, thus allowing these mobile technologies to delve into teaching within different branches of knowledge, both in practice and in theory. This is known as e-learning [10–11].

Implementing this learning process is essential for students and learners because certain topics may prove to be extensive, complex, or both for students to understand and memorize. E-learning is becoming an attractive learning and training modality with broad social roots and a growing presence in traditional classroom-oriented universities [12].

An interesting area of this learning process focuses on mobile technologies (m-learning). This is a scenario in which students can move away from the everyday context and start developing skills from anywhere and at any time because mobile tools are not constrained to a face-to-face classroom. This aspect is critical within the teaching and learning environment in higher education since students can function and develop professional, social, intercultural, and even interpersonal skills in any environment [13]. Furthermore, accessing information from a mobile application allows students to obtain a selected and/or restricted version of the information compared to the open information found on the Internet [14].

E-learning and D-learning were some of the alternatives to traditional teaching that allowed health students to continue their learning processes during the COVID-19 pandemic [15]. This allowed to shorten distances and guarantee the development of the academic community [16], time flexibility in addition to E-learning being valuable to enhance and progress learning [17]. However, some researchers found evidence that the impact of COVID-19 on principals and teachers was psychological distress, addiction to social networking, and pandemic-related burnout, as well as a significant impact on quality of life, and levels of loneliness and happiness.

According to the above, there are many challenges and opportunities that technology-mediated education is gives us [18], in terms of learning with quality, efficiency, and effectiveness, inside the role of the teacher-student, mental and physical health, and teaching-learning needs in the health professions due to its theoretical-practical component, especially physiotherapy.

Now, physical therapy care is crucial work in professional clinical practice. Physical therapy practice is designed for patient management in different health environments and conditions. In this sense, physical therapy must use assessment and testing methods to enhance professional action [19]. In the APTA care model, examination seeks to identify possible deficiencies arising from tissue pathology, together with the need for health prevention [20–21]. A detailed patient interview focusing on function limitations helps therapists recognize patterns and body functions that may be affected [22]. Based on the above, the therapist may conduct tests and apply specific measures to research the diagnostic hypothesis.

Although the care model is well defined, some flaws are evident during its implementation [23], mainly owing to data loss [24], not strictly adhering to application instructions for some tests and measures [25], the need to reduce care time, and increasing assessment effectiveness [26].

The necessity to make learning more flexible [27] and, above all, overcome the generation gap by moving from traditional didactic tools to mobile learning (m-learning) [28] as students are constantly looking for innovation and technology and prefer teams, groups, and multitasking [29].

As technologies can help solve this problem, this project proposes a method for integrating ICTs and the APTA Guide to Physical Therapist Practice to facilitate clinical documentation drawn up by physical therapy students.

1.2 State of the art

When implementing technological tools in the classroom, students become the protagonists of their own learning process, and start developing skills and solving problems [30]. The integration of ICTs into physical therapy educational processes generates educational models wherein technologies are a supporting tool and supplement the achievement of competencies in undergraduate training [31].

Physical therapy examination is a critical element for physical therapists that crosses over into their professional practice and decision-making [32]. Hence, this process must be enhanced in terms of information management, care-time efficiency, instruction, and cutoff point access for healthcare patients, thus improving diagnostic accuracy and, in turn, the rationalization of physical therapy services and healthcare costs.

In this sense, [33] states that applications in the health area improve clinical decision-making and give greater accuracy, efficiency, and productivity. An example of the use of applications for examination that have demonstrated reliability are the applications of goniometers [34]. In addition, applications reinforce traditional learning and have shown to improve the skills of pain examination, palpation, and shoulder ultrasound.

The literature review describes the variety of technological devices that foster continuous healthcare improvements among the population. However, research studies on the development of physical therapy assessment processes and centralized tools are few, and those reported in the literature usually range from monitoring to measuring specific variables, as discussed in [35].

In a review [36], we identified 15 physiotherapeutic assessment applications of specific measurement categories such as joint mobility, gait, and posture, among others, but none that compiled the APTA and supported learning-teaching processes exist for learning core techniques, for frozen shoulder rehabilitation [37], or in different body segments, as well as for monitoring, education, or intervention.

The Guide to Physical Therapist Practice is the guide that describes physical therapy practices for therapists and healthcare policymakers. Examination results are obtained through tests and check-ups conducted on the patient [19].

Mobile learning, or m-learning, is defined as the process that brings together the use of mobile devices in pedagogical practices in a remote or face-to-face environment. M-learning customizes learning based on student profiles and provides nonrestrictive access to both educational and academic activities. Mobile devices and applications facilitate recording data in real time, retrieving information, promoting work, and autonomous and collaborative learning [38]. For this reason, [39] claims that students in higher education usually favor this learning process.

Currently, there are no applications based on the Guide to Physical Therapist Practice that may work as a learning and teaching tool. However, several applications can be used to monitor and manage health and well-being. These applications are known as m-health [40]. Today, a wide variety of m-health applications are available. Most of these applications aim at boosting student and teacher performance within the pedagogical environment [41].

In this sense, the application proposal presented not only collects information from 26 APTA measurement categories organized by cardiopulmonary, neuromuscular, and musculoskeletal systems, but also supports traditional teaching and provides an interface that displays the information and guides the student and teacher by facilitating the acquisition and understanding of the tests and measurements through descriptions of the test objective, target population, step-by-step of each test, reliability, and validity data.

Given the above, how could the information from the APTA Guide to Physical Therapist Practice be compiled into a tool to support the learning process for physical therapy students and future therapists?

1.3 Goals

Within this context, we hereby propose designing a mobile application prototype to support physical therapy assessment learning processes at the Universidad de Santiago de Cali. For these purposes, the following goals are conceived: to propose a mobile device-based technological solution within the educational and practical context of physical therapy with its requirements and needs; to design this technological solution so that it may support the learning process related to the Guide to Physical Therapist Practice; to develop a mobile application prototype that supports the understanding and study of the Guide to Physical Therapist Practice; and, finally, to validate the usability of this prototype through tests.

2 METHODOLOGY

2.1 Introduction to the methodology

This project was developed under the Personal Software Process (PSP) methodology. The PSP methodology aims at improving time management and productivity within the group of developers, and it is divided into six main phases comprised of multiple activities each. However, we decided to compress the project into four stages: planning, design, development, and validation.

2.2 Methodology stages

The following activities included the planning, coding of the previously designed models, and the compilation, testing, and evaluation of the system model against the project goals previously established above to guarantee that the goals have their proper documentation.

1. Planning

   The activities conducted at this stage helped establish the objectives and scope of the project. First, the project requirements were gathered to identify the main system functions desired and establish its high-level architecture. The requirements identified were assessed in detail to determine which tools and technologies best fit the requirements. This was essential for reaching the first goal.

2. Design

   This stage seeks to design the technological solution for the project. Therefore, we assessed different alternative designs to provide a detailed description of the solution through the 4 + 1 model. This is a software engineering model that views software architecture from multiple perspectives using the Enterprise Architect program.

3. Development.
In this stage, the solution prototype is developed. The designs from the previous stage were analyzed to proceed with the coding and compilation of the main solution modules. Finally, the modules developed were integrated into the solution.

4. Validation
Finally, in the validation stage, the solution development process and its operation were explained. In addition, the different errors and problems identified in the previous phase and throughout its construction were addressed. For this, the corresponding detailed solution and description documentation were drawn up. Finally, we conducted a usability test of the prototype with the target population, thus achieving the last goal established.

3 DEVELOPMENT

3.1 Introduction to the development process

The development project phase was conducted by a multidisciplinary team comprised of two systems engineering students, a physical therapy student, two professional physical therapy professors, and a professional system engineering professor.

3.2 Development implementation

1. Planning
Constant multidisciplinary support was critical in the planning stage, and more specifically for the analysis, design, and implementation activities with the identification, categorization, and creation of information domains. Furthermore, we also used the Cocomo model, which estimates software and effort costs (person/month) and execution length, where E = effort (man/month) and $KLOC$ = estimated number (thousands) of code lines required for the project. Analyze Equation 1 and Equation 2.

$$E = a\ KLOC^{b} \tag{1}$$

$$D = c\ (E)^{d} \tag{2}$$

We scheduled periodic brainstorming meetings to identify the main issues, needs, and requirements associated with the teaching and student learning processes in the area of physical therapy, specifically with an emphasis on adopting the Guide to Physical Therapist Practice. In addition, we also scheduled weekly follow-up meetings to discuss solution development.

The constant feedback received in these meetings facilitated the identification of content errors, bugs, and inconsistencies. Hence, we reviewed the prototype concept on different occasions, fine-tuning the understanding of the entire team.

The main results of these meetings also prompted the writing of user stories based on the results of the passive observation process performed by the different students and professors. The main software functionalities were described in natural language, thus obtaining a general description and a validation case, which allowed us to determine whether the corresponding goal had been achieved.

This information was compiled by the team and submitted for discussion, a process that largely refined user stories, fostered requirement identification, and contributed to the development of our first consolidated prototype in a high-level diagram.

After the first prototype had been identified, the Knowledge Classification process was proposed. However, this process was conducted within limits that exceed the purpose of this document. The large amount of examination process information scattered across the World Wide Web (WWW) forced the team to propose a working model to collect this information in the same location while considering that this information is not very sensitive and does not require further security measures because it is freely available on the Internet.

For these purposes, a shared spreadsheet was used to create a category matrix (see Table 2 below), where all the known tests were recorded (see Table 3 below), as well as any additional information. This process was called content validation. The domains defined are presented in Table 1 below.

Table 1. Domain matrix

Title	Definition	Objective
D1	DD1	DO1
Dn	DDn	DOn

Notes: D1. Domain Title, DD1. Domain Definition, DO1. Domain Objective.

Table 2. Category matrix

Title	Definition	Objective
C1	CD1	CO1
Cn	CDn	COn

Notes: C1. Category Title, CD1. Category Definition, CO1. Category Objective.

Table 3. Test/measuares matrix

Title	Definition / Objective	Scoring / Interpretation	Author / Country / Year	Link / Source
T1	TX1	TP1	TA1	TE1
Tn	TXn	TPn	TAn	TEn

Notes: Tn. Title, TXn. Definition / Objective, TPn. Scoring / Interpretation, TAn. Author, TEn. Source.

Subsequently, a JSON (JavaScript Object Notation) file was created to compile the information so that it could be read by the solution. Since this file is similar to a dictionary, it becomes a source of information that may be quickly interpreted. This information was later used to create and model collections that were ultimately included in the database.

2. Design

The design phase starts with the information collected in the planning phase. We also used domain diagrams to identify the entities involved and their corresponding attributes, which led to the creation of the Use Case diagram. In addition, to achieve a functional prototype within the proposed schedule, we only selected requirements with a high priority level.

These diagrams helped improve understanding among all stakeholders and the development team. Next, we proceeded with the design of a high-level architecture diagram, which described the technologies, layers, and communication interfaces between the mobile application, its main modules, and the information source or repository. In addition, a context diagram was designed to better comprehend how solution components interacted with each other. Due to the dimensions, some figures are available as annexes by means of a link as follows: (See Appendix 1)

To specify and achieve a higher level of detail, we developed selected UML diagrams, taking the 4 + 1 model as a reference for the description of an information system as proposed by Kruchten [42]. The layout and design process were carried out with the help of the Enterprise Architect work tool [43], a software program licensed by Universidad Santiago de Cali and available on a shared server with remote access for students.

Initially, for the logical view, we developed sequence diagrams to improve our understanding of the messages exchanged among the different solution components and the flow of information within the application. Here, we included components with a high level of abstraction, thus proposing a component architecture influenced by the Bloc (Business Logic Component) pattern as well as a clean architecture as described in [44].

The latter was used to differentiate component grouping into more specific packages, thereby improving development performance and answering two main questions regarding the modeled entity. Who are you? (Based on the concept) And what type are you? (Based on the function). This generated greater cohesion within the code and allowed the information from each entity to be located.

We continued with the design of the component or package diagram to describe not only the internal structure mentioned above but also to identify critical information exchange points and generalize components to make them highly reusable. Moreover, we established the connection with different information repositories.

3. Development

The development stage was conducted over a prudent period of time, wherein incremental deliveries of the functionalities and the main requirements were generated. The information generated in the planning stage was addressed in a JSON file, a lightweight format for storing and transporting data from a server or repository to a web page or client for quick and easy consumption, generating a database with all information in attribute-value pairs recorded within the JSON format [45]. Finally, these entities were modeled in a local database, migrating all the information provided by the file to a Hive DB. This is a nonrelational, lightweight, and fast database written in the Dart programming language.

The main user requirements were addressed to generate a functional prototype that would subsequently allow for unit and usability tests to be conducted. For this reason, the information was consumed directly from the file, and all user interfaces were developed [46].

Due to the clean architecture and design pattern defined in the previous stage, the development team was able to obtain a better interpretation of the solution, which allowed them to achieve a higher level of incident targeting. In addition to correctly separating the entities involved in the solution, the latter were modeled for future use in the different business logic components.

4. Validation

For this project, we used the usability tests recommended by [47], applying Maze as middleware. Maze is specialized software for conducting online usability tests with multiple study subjects. These tests were considered all testing conducted by physical therapy students as long as they were part of their professional practice. Next, three missions to be completed by students through interfaces were proposed [48]. These tests will determine the average rate of erroneous clicks and the average time that users spend on each screen attempting to complete the corresponding mission.

4 RESULTS

4.1 Introduction to the results

The following section discusses the results from each project stage. These results evidence the work conducted and the evolution obtained throughout development.

4.2 Results from each stage

1. Results from the Planning Stage

The real values were replaced according to the Cocomo model to estimate effort and development times. These data were obtained by estimating the number of lines of code required for the project. Here, a, b, c, and d, are constants calculated based on a simple software table. The results obtained were 7.04 (man/month). For a clearer understanding, see Equation 3. In turn, this result is included in the development time equation, thus obtaining an estimate of 5.24 months. See Equation 4.

$$E = 3.2\ (2.119)^{1.05} = 7.0402 \tag{3}$$

$$D = 2.5\ (7.04)^{0.38} = 5.2482 \tag{4}$$

As previously mentioned above, a multidisciplinary research study was conducted to define the planning stage. The results yielded a systematic literature review arranged in a matrix containing different papers where physical therapy and mobile technologies are jointly mentioned. For these purposes, different search variables and combinations thereof were used in several databases, such as IEEE Explorer, PubMed, Academic Google, Sage Journals, ScienceDirect, and Scopus. (See Appendix 2).

Subsequently, to better understand the functionalities and requirements that end users expect in the final product, ten user stories were developed. Eight of these stories considered students as the requesting party, and the remaining two focused on teachers as requesters. (See Appendix 3).

Most of the user stories focused on information from the APTA Guide to Physical Therapist Practice regarding domains, categories, and tests. However, visual materials from the APTA Guide to Physical Therapist Practice are also required, along with the implementation of an API that provides local healthcare news.

Then, user requirements were defined and divided into functional requirements, nonfunctional requirements, and software and hardware requirements. The project scope was defined as a mobile application prototype with the ability to display general information from the Guide to Physical Therapist Practice [49]. To summarize, six of the most important user requirements are described below. (See Appendix 4).

User requirements:

a) The application must be accessed without requiring user registration.
b) Any eligible content from the APTA Guide to Physical Therapist Practice must be readily accessible (if linked).

c) The application must allow users to view the latest news associated with the corresponding healthcare area and to access their news source or origin.

Nonfunctional requirements:

a) Response time: The system must be able to quickly access information.
b) Performance: The system must have an acceptable overall performance (fluidity).
c) Information: The system must display the information in a concise and orderly manner.

In this manner, these would be the results obtained in the planning stage. According to the methodology proposed, these results correspond to the scope of the solution proposal (the current situation assessment).

2. Results from the Design Stage

As previously mentioned above, as part of the application design process, several diagrams were developed based on the 4 + 1 model, also known as the Kruchten model, and using the Enterprise Architect software to improve the understanding of product stakeholders and the whole work team. This corresponds to the design goal of the proposed solution. For example, for the logical view, the sequence diagram was prepared. For the deployment view, the package diagram was developed. For the process view, the activity diagram was issued. For the physical view, a deployment diagram was created. Finally, for the +1 view, the use case and scenario diagram were constructed. (See Appendix 5). Some of these diagrams, considered as critical by the development team, are described below:

Context Diagram: As it may be observed in Figure 1, five components were considered in the context diagram: DataBase (Hive), News (ApiNews), User, the APTA Guide to Physical Therapist Practice, and the main "APTA - main APP" component.

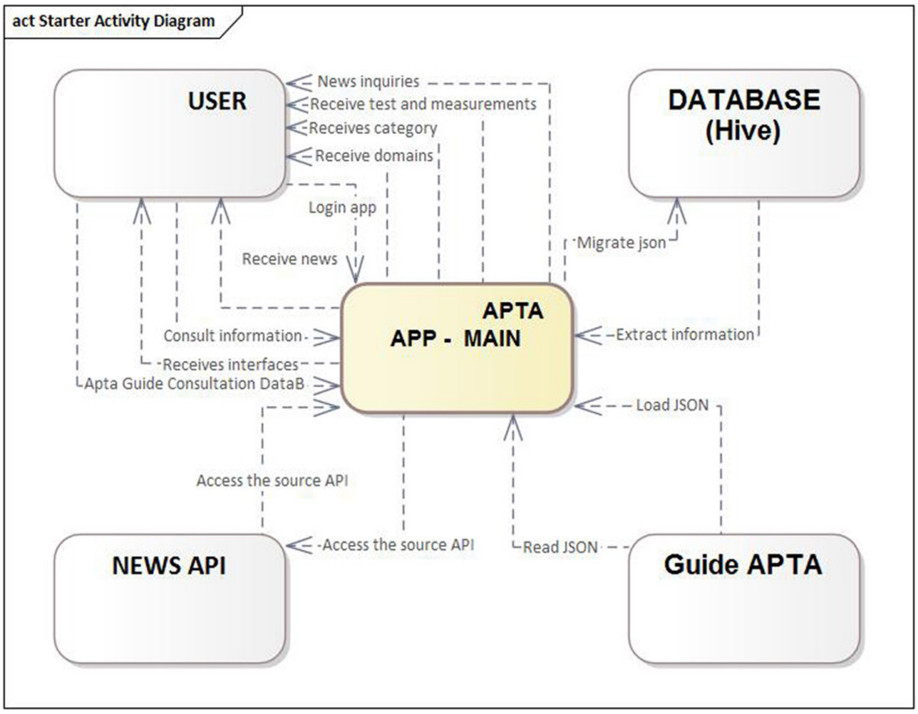

Fig. 1. Context diagram

a) Logical View (Sequence Diagram):

For the logical view of the 4 + 1 model, we developed a sequence diagram, which describes three system components together with the User actor (View, BLoc, and Repository).

- Use Cases: Domain
  The first action is to access the APTA Guide to Physical Therapist Practice <View>. Later, the system displays the available domains, and the user makes the corresponding selection. Once the selection has been made, the current domain is updated <BLoC>, and the system queries the domain categories. The list of categories is searched in <Repository>, which returns the list of categories to <BLoc>. Next, the categories are updated, and the list of categories is finally displayed to the user.

- Use Case: Categories
  The first action is to access the <View> domain. Then, the domains are displayed to the user and the user selects the category stored within domain. View updates the current category in <BLoc> and a query is conducted on category information. Next, the information is queried in <Repository> and the results are returned to <BLoC>. The category is updated again, and the list of measures is queried in<Repository>, which returns the corresponding list of measures. The categories view is updated in <View> and the category is finally displayed.

- Use Case: Test.
  Firstly, the category must be accessed in the <View> component. Later, the specific category is displayed, the user selects the test, and <BLoC> updates the test. Next, this component information is queried, and an information search is conducted by ID in <Repository>. The test is updated. Once this has been completed, the test is updated in the view and the information is displayed to the user.

- Use Case: News
  Finally, in the "News" use case, the news is accessed in the <View> component, recent news are queried in <BLoC>, and the latest news items are requested from <Repository>. Subsequently, <Repository> returns a response with the news to BLoC, the list of news items is updated and displayed to the user.

b) Deployment View (Component Diagram).

As may be observed in Figure 2, the general component diagram was developed based on a clean architecture. Hence, a package structure is denoted.

c) View (Scenario Diagram)

Six possible scenarios that may take place within the system and their interactions with the different components are described in the scenario diagram. (See Appendix 6).

- Scenario 1: The application is accessed for the first time.
  Use Case: Application Presentation.
  The steps could be described as follows:
  The user accesses the application for the first time.
  The application displays the Presentation view.

The user scrolls through Presentation views that describe the content.
The application displays the Main Screen.

- Scenario 2: The user accesses the "APTA Guide," Description and General Information view.
  Use Case: APTA Guide Information.
  The steps could be described as follows:
  The user enters the "APTA Guide" view.
  The mobile application displays information from the APTA Guide and its domains.
  The user selects "Additional information."
  The application displays the corresponding information (objectives, implementation, and sources).

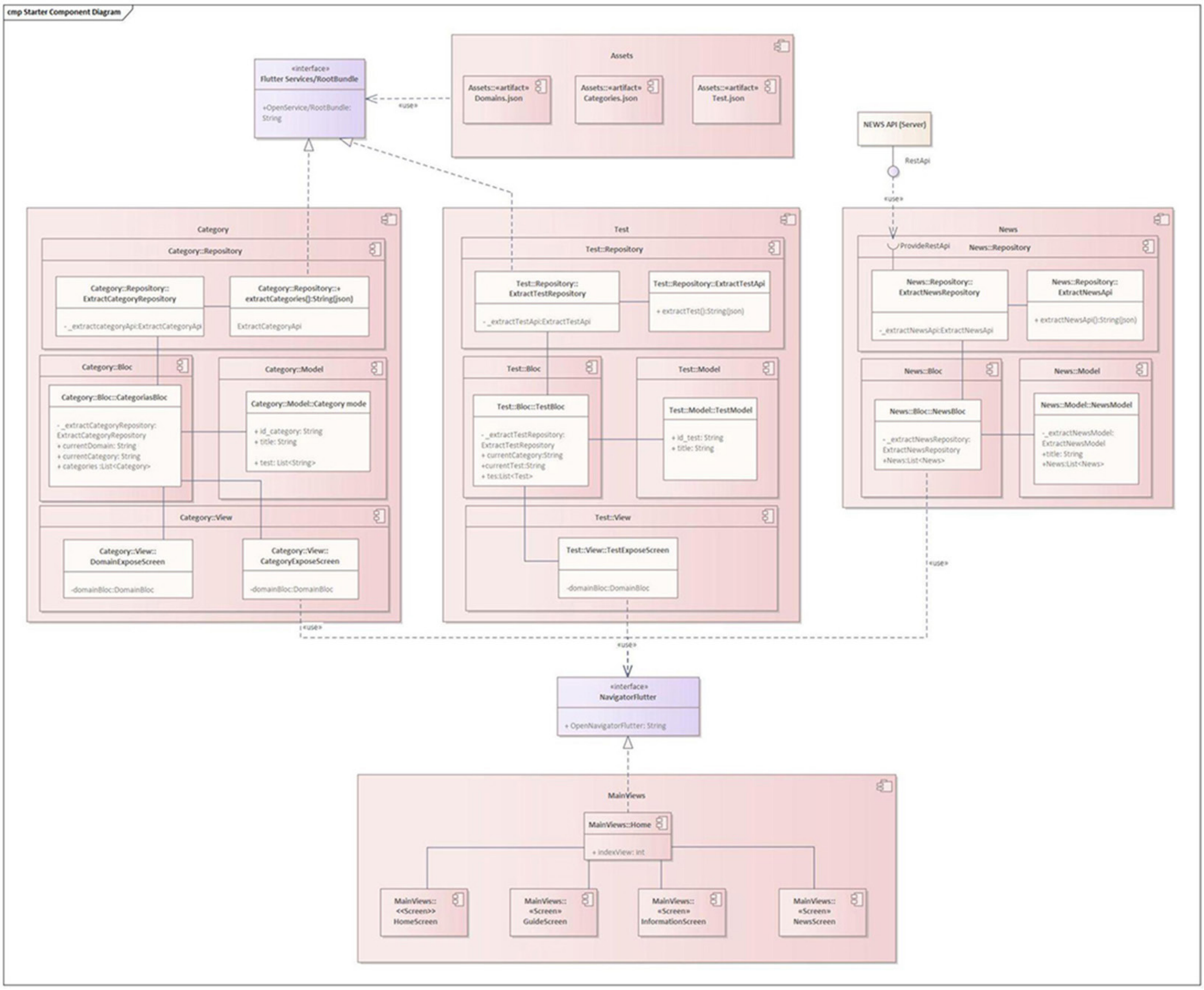

Fig. 2. Component diagram

- Scenario 3: The user accesses the "APTA Guide" – Specific Domain view.
  Use Case: Domains.
  The steps could be described as follows:

The user enters the "APTA Guide" view.
The application displays the number of domains configured.
The user selects the desired domain.
The application displays general information for the selected domain, as well as its categories.
The user navigates through the general information of the domain and its categories.

- Scenario 4: The user selects the desired category.
  Use Case: Category.
  The steps could be described as follows:
  The user enters a specific domain.
  The application displays general information for the selected domain, as well as a list of its related categories.
  The user selects the desired category.
  The application displays general information for the selected category, as well as its corresponding tests and measures.
  The user can navigate through the general information of the category (Category ID and Parent Domain), its tests and measures.

- Scenario 5: The user selects the desired test
  Use Case: Test.
  The steps could be described as follows:
  The user enters a specific category.
  The application displays general information for the category, as well as a list of tests.
  The user selects the desired test.
  The application displays general information for the selected test, as well as its objectives and application procedures.
  The user can navigate through the general information, Category ID and Parent Domain, and its application procedures.

- Scenario 6: The user accesses the "news" section.
  Use Case: News.
  The steps could be described as follows:
  The user accesses the news section.
  The application queries the most recent news items.
  The application displays a list of the most recent news items.
  The user selects the desired news item.
  The user is redirected to the news item source where the user will be able to read the selected news item.

3. Results from the Development Stage

Within the results from the development stage, a private repository hosted on GitHub was obtained as a version manager and a mobile application that allows users to query information from the APTA Guide to Physical Therapist Practice in an organized and structured manner at any time and from any location. Based on this information, the general structure of the database that will host the different domains, categories, and key-value pair tests was obtained. A quick query of relevant news items for students will allow them to expand their current knowledge. These results are relevant for achieving our prototype development goal.

4. Results from the Validation Stage

More than 40 students participated in the usability tests, with 20 of them executing exercises from the application, which fulfilled our validation goal. After this observation, the following results were achieved. (To appreciate full results, see Appendix 7).

a) Mission: Access the APTA Guide.

In this first mission, the objective is to access the general information from the Guide to Physical Therapist Practice and all its domains. For this mission, participants are asked to access the Cardio-pulmonary domain. To understand this, see Figure 3.

Fig. 3. Results from the first mission (Generated through the Maze App)

b) Mission: Access a Category.

In this second mission, participants must access one of the domains from the APTA Guide, view its information, view the list of categories, and finally access the "Aerobic Capacity/Endurance" category. See Figure 4 below.

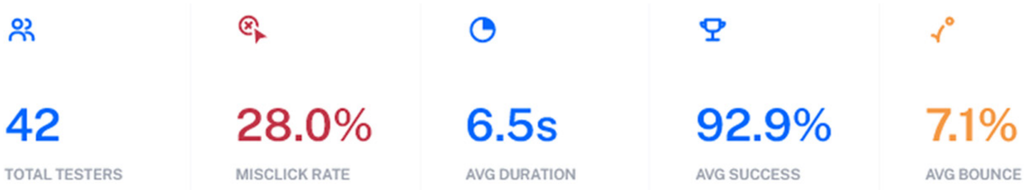

Fig. 4. Results from the second mission (Generated through the Maze App)

c) Mission: Access a Test and Measure.

In this last mission, participants must use the application to access one of the tests from the categories. Specifically, they are asked to locate the "Rockport Test" and access all its information. See Figure 5 below.

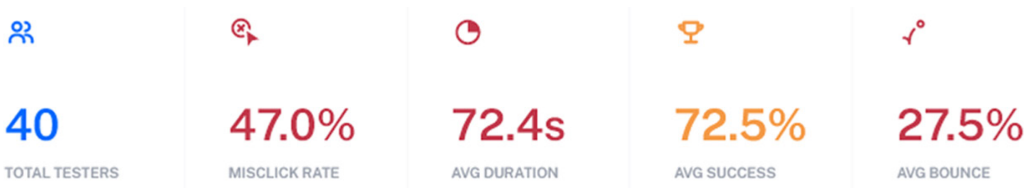

Fig. 5. Results from the third mission (Generated through the Maze App)

5 DISCUSSION

5.1 Introduction to the discussion

Based on the results obtained, we used the right application design and development methodology for achieving our proposed objective of "Designing a mobile application prototype to support learning processes in physical therapy assessment at Universidad de Santiago de Cali." The results also demonstrate that we fulfilled the required competencies for solving the issues faced by physical therapy students regarding the APTA Guide to Physical Therapist Practice, such as not having a quick and practical query tool that may facilitate their access to APTA Guide content and other relevant documentation [50].

The UNESCO report states that smartphones are increasingly used and describes 21 mobile learning initiatives in Latin America, which are distributed with five in Chile, four in Argentina and the same amount in Mexico, three in Colombia, and an initiative in El Salvador, Honduras, Paraguay, and Peru. The initiatives are aimed at improving pedagogy and strengthening support for professors and teachers.

Also, the Colombian projects are: Roots of Mobile Learning, BlueGenesis, and the National Literacy Program, among others [51]. Research concluded that there is feasibility of mobile learning among university students, as well as feasibility of time and willingness of students to use mobile devices in class [52].

5.2 Discussion of the results from the planning stage

The results from the Cocomo model were very close to the execution time and performance level originally estimated for the project.

In addition to providing these estimates, the planning stage was also critical for kick-starting and defining project conceptualization. However, this stage was also challenging when considering the composite perception of diverse knowledge encompassed in the project as a consequence of being an interdisciplinary project developed by and between the Schools of Engineering and Health Care [53–54].

5.3 Discussion of the results from the design stage

In the design stage, the Kruchten model was the most competent option. This model allowed us to view a larger project overview for mapping. The Enterprise Architect software helped us build a more robust and understandable project using standards related to the diagrams proposed, thus improving understanding among the members of the development group and also providing greater fluidity in the implementation process.

5.4 Discussion of the results from the development stage

The results from the development stage identified some setbacks during information consumption and later during the migration of the local information repository to a key-value database. This solution of migrating information to a nonrelational local database was proposed due to the dynamic structure of the documents, their large number, and the high query speed exhibited by nonrelational databases.

5.5 Discussion of the results from the testing stage

In the testing stage, we identified some compatibility and adaptability issues regarding graphical interface designs, and the corresponding changes were implemented. In the development stage, some possible future user requirements were also determined. Hence, they were considered new requirements for implementation in the next release of the application.

The findings from the usability tests were significant since most participants successfully completed the missions requested. Here, over 70% completed all missions, and over 90% successfully completed at least two missions.

In addition, the possibility of implementing a software security strategy, such as encryption of the local database, was assessed. However, as mentioned in the development stage, the information is in the public domain and can be easily found on the Internet. Therefore, there is no pressing need to implement these security measures.

6 CONCLUSIONS

6.1 Conclusions from the planning stage

As the Cocomo model was so successful with the actual results in terms of effort and time length estimation, we propose using this model again in future development iterations of this interdisciplinary project.

Holding regular meetings was also critical for identifying requirements and conceptualizing the project. The members of the development group also claimed that participating in an interdisciplinary project by and between the Schools of Engineering and Health Care was quite fascinating, especially since compiling so much scattered information into a single mobile application and then properly managing and disseminating said content proved to be quite a challenging task.

6.2 Conclusions from the design stage

The design proposed features a fairly scalable architecture that supports pertinent changes according to user or stakeholder needs. Furthermore, the creation of diagrams depending on the proposed views provides a fairly simple and understandable overview for the entire research and development team. These diagrams became an essential bridge for communication and solution planning.

6.3 Conclusions from the development stage

The Business Logic Component architecture and the influence of clean architecture were paramount for prototype implementation due to the abstraction of entities and logical components, thereby providing greater scalability when developing a second release with new features. In addition, this stage focused on the obstacles facing the implementation process and on facilitating their prompt solution.

6.4 Conclusions from the testing stage

This mobile application helps and supports students in their learning process, especially due to its usability levels and optimal response times. The tests that were conducted at Universidad Santiago de Cali were key to understanding how our application was perceived by the academic community. In addition, continuous feedback was generated for future releases.

7 FUTURE WORK

7.1 Future Work for the introduction stage

Owing to our implementation results, we expect to apply some of the main aspects herein in future software projects in terms of planning and assessment. Throughout this implementation, new ideas applicable to the prototype have arisen. These ideas were left open and are expected to be revisited for future releases. Below, we highlight some ideas that can be developed through a new research project. These ideas improve the model proposed but were not developed as part of this paper due to planning and time constraints.

7.2 Future work for the planning stage

We would like to include new sections that expand the domain of information within the application. In addition, we would like to implement a new research methodology that may allow us to collect more information.

7.3 Future work for the design stage

In the planning stage, we used the 4 + 1 model. However, depending on project scoping and requirements, some of its views were not really required.

7.4 Future work for the development stage

We recommend implementing an authentication system that may provide a more personalized user experience for students. This system will obtain more information from each student to create mobile application profiles. In addition, we propose including new sections where the administrator can control the flow of information from different categories, domains, and tests.

7.5 Future work for the validation stage

In future releases, we expect to continue using the Maze application for usability tests. However, for this project, in tests, we only used the freeware version of this application. In future projects, we would like to use the paid version of this application to increase the number of test takers.

8 ACKNOWLEDGMENT

This research has been funded by Dirección General de Investigaciones of Universidad de Santiago de Cali under call No. 01–2023.

9 REFERENCES

[1] A. R. F. de Oliveira and M. S. D. M. Alencar, "O uso de aplicativos de saúde para dispositivos móveis como fontes de informação e educação em saúde," *RDBCI: Revista Digital de Biblioteconomia e Ciência da Informação*, vol. 15, no. 1, p. 234, 2017. https://doi.org/10.20396/rdbci.v0i0.8648137

[2] T. Karakose, R. Yirci, and S. Papadakis, "Examining the Associations between COVID-19-Related Psychological Distress, Social Media Addiction, COVID-19-Related Burnout, and Depression among School Principals and Teachers through Structural Equation Modeling," *Int J Environ Res Public Health*, vol. 19, no. 4, 2022. https://doi.org/10.3390/ijerph19041951

[3] J. Portnoy, M. Waller, and T. Elliott, "Telemedicine in the Era of COVID-19," *Journal of Allergy and Clinical Immunology: In Practice*, American Academy of Allergy, Asthma and Immunology, vol. 8, no. 5, pp. 1489–1491, 2020. https://doi.org/10.1016/j.jaip.2020.03.008

[4] N. O. García, M. F. D. Velásquez, C. A. T. Romero, J. H. Ortiz, and O. I. Khalaf, "Remote Academic Platforms in Times of a Pandemic," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 21, pp. 121–131, 2021. https://doi.org/10.3991/ijet.v16i21.25377

[5] C. A. T. Romero, J. H. Ortiz, O. I. Khalaf, and W. M. Ortega, "Software Architecture for Planning Educational Scenarios by Applying an Agile Methodology," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 8, pp. 132–144, 2021. https://doi.org/10.3991/ijet.v16i08.20603

[6] F. Prasetya, B. R. Fajri, R. E. Wulansari, Primawati, and A. Fortuna, "Virtual Re ality Adventures as an Effort to Improve the Quality of Welding Technology Learning during a Pandemic," *International Journal of Online and Biomedical Engineering*, vol. 19, no. 2, pp. 4–22, 2023. https://doi.org/10.3991/ijoe.v19i02.35447

[7] T. Karakose, T. Y. Ozdemir, S. Papadakis, R. Yirci, S. E. Ozkayran, and H. Polat, "Investigating the Relationships between COVID-19 Quality of Life, Loneliness, Happiness, and Internet Addiction among K-12 Teachers and School Administrators—A Structural Equation Modeling Approach," *Int J Environ Res Public Health*, vol. 19, no. 3, 2022. https://doi.org/10.3390/ijerph19031052

[8] M. Kalogiannakis and S. Papadakis, "The use of Developmentally Mobile Applications for Preparing Pre-Service Teachers to Promote STEM Activities in Preschool Classrooms," *Mobile Learning Applications in Early Childhood Education*, pp. 82–100, 2020. https://doi.org/10.4018/978-1-7998-1486-3.ch005

[9] R. S. Rajasree, G. S. Gopika, K. M. Sree, and C. A. T. Romero, "The Role and Impact of Federal Learning in Digital Healthcare," *Handbook of Research on Technical, Privacy, and Security Challenges in a Modern World*, pp. 127–147, 2022. https://doi.org/10.4018/978-1-6684-5250-9.ch007

[10] S. F. Shetu, M. M. Rahman, A. Ahmed, M. F. Mahin, M. A. U. Akib, and M. Saifuzzaman, "Impactful E-learning Framework: A New Hybrid form of Education," *Current Research in Behavioral Sciences*, vol. 2, 2021. https://doi.org/10.1016/j.crbeha.2021.100038

[11] A. P. Sasmito, D. Kustono, Purnomo, H. Elmunsyah, D. Nurhadi, and P. Sekarsari, "Development of Android-Based Teaching Material in Software Engineering Subjects for Informatics Engineering Students," *International Journal of Engineering Pedagogy*, vol. 11, no. 2, pp. 25–40, 2021. https://doi.org/10.3991/ijep.v11i2.16299

[12] V. Milićević *et al.*, "E-learning Perspectives in Higher Education Institutions," *Technol Forecast Soc Change*, vol. 166, 2021. https://doi.org/10.1016/j.techfore.2021.120618

[13] S. K. Basak, M. Wotto, and P. Bélanger, "E-learning, M-learning and D-learning: Conceptual Definition and Comparative Analysis," *E-Learning and Digital Media*, vol. 15, no. 4, pp. 191–216, 2018. https://doi.org/10.1177/2042753018785180

[14] S. U. Kim, I. Martinović, and S. S. Katavić, "The Use of Mobile Devices and Applications for Health Information: A Survey of Croatian Students," *Journal of Librarianship and Information Science*, vol. 52, no. 3, pp. 880–894, 2020. https://doi.org/10.1177/0961000619880937

[15] A. Naciri, M. Radid, A. Kharbach, and G. Chemsi, "E-learning in Health Professions Education During the COVID-19 Pandemic: A Systematic Review," *J Educ Eval Health Prof*, vol. 18, p. 27, 2021. https://doi.org/10.3352/jeehp.2021.18.27

[16] A. Seymour-Walsh, A. Bell, A. Webber, and T. Smith, "Adapting to a New Reality: COVID-19 Coronavirus and Online Education in the Health Professions," *Rural Remote Health*, vol. 20, p. 6000, 2020. https://doi.org/10.22605/RRH6000

[17] M. M. Zalat, M. S. Hamed, and S. A. Bolbol, "The Experiences, Challenges, and Acceptance of E-learning as a Tool for Teaching During the COVID-19 Pandemic Among University Medical Staff," *PLoS One*, vol. 16, no. 3, 2021. https://doi.org/10.1371/journal.pone.0248758

[18] T. Trinh Thi Phuong, N. Danh Nguyen, D. Ngo Van, H. Nguyen Thi Thu, and T. Nguyen Chi, "Factors Influencing the Use of Digital Games in Teaching: An Exploratory Study in the Context of Digital Transformation in Northern Vietnam," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 18, no. 08, pp. 164–182, 2023. https://doi.org/10.3991/ijet.v18i08.36243

[19] American Physical Therapy Association, "Guide to Physical Therapist Practice, Second Edition," *Phys Ther*, vol. 81, no. 1, pp. 9–746, 2001.

[20] A. M. Jette, "Toward a Common Language of Disablement," *Journals of Gerontology – Series A Biological Sciences and Medical Sciences*, vol. 64, no. 11, pp. 1165–1168, 2009. https://doi.org/10.1093/gerona/glp093

[21] E. Doyle, "Appraisal of Clinical Practice Guideline: Patellofemoral Pain: Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability and Health From the Academy of Orthopaedic Physical Therapy of the American Physical Therapy Association," *J Physiother*, vol. 66, no. 2, p. 134, 2020. https://doi.org/10.1016/j.jphys.2020.02.008

[22] C. Doody and M. McAteer, "Clinical Reasoning of Expert and Novice Physiotherapists in an Outpatient Orthopaedic Setting," *Physiotherapy*, vol. 88, no. 5, pp. 258–268, 2002. https://doi.org/10.1016/S0031-9406(05)61417-4

[23] M. J. Hammond and M. E. S. P. P. S. Australia, "Clinical Examination and the Physiotherapist," *Aust J Physiother*. 1969. https://doi.org/10.1016/S0004-9514(14)61072-2

[24] K. Vader *et al.*, "Implementing a New Physiotherapist-Led Primary Care Model for Low Back Pain: A Qualitative Study of Patient and Primary Care Team Perspectives," *BMC Primary Care*, vol. 23, no. 201, 2022. https://doi.org/10.1186/s12875-022-01817-5

[25] C. Doody and M. McAteer, "Clinical Reasoning of Expert and Novice Physiotherapists in an Outpatient Orthopaedic Setting," *Physiotherapy*, vol. 88, no. 5, pp. 314–326, 2002. https://doi.org/10.1016/S0031-9406(05)61417-4

[26] T. Russell, "Goniometry via the Internet," *Australian Journal of Physiotherapy*, vol. 53, no. 2, p. 136, 2007. https://doi.org/10.1016/S0004-9514(07)70051-X

[27] B. Olivier, M. Verdonck, and D. Caseleijn, "Digital Technologies in Undergraduate and Postgraduate Education in Occupational Therapy and Physiotherapy: A Scoping Review," *JBI Evid Synth*, vol. 18, no. 5, pp. 863–892, 2020. https://doi.org/10.11124/JBISRIR-D-19-00210

[28] B. Shatto and K. Erwin, "Teaching Millennials and Generation Z: Bridging the Generational Divide," *Creat Nurs*, vol. 23, no. 1, pp. 24–28, 2017, https://doi.org/10.1891/1078-4535.23.1.24

[29] M. Lozano-Lozano *et al.*, "The Ecofisio Mobile App for Assessment and Diagnosis Using Ultrasound Imaging for Undergraduate Health Science Students: Multicenter Randomized Controlled Trial," *J Med Internet Res*, vol. 22, no. 3, p. e16258, 2020. https://doi.org/10.2196/16258

[30] I. K. Suartama, P. Setyosari, Sulthoni, and S. Ulfa, "Development of an Instructional Design Model for Mobile Blended Learning in Higher Education," *International Journal of Emerging Technologies in Learning*, vol. 14, no. 16, pp. 4–22, 2019. https://doi.org/10.3991/ijet.v14i16.10633

[31] M. Ivanović, A. K. Milićević, V. Aleksić, B. Bratić, and M. Mandić, "Experiences and Perspectives of Technology-Enhanced Learning and Teaching in Higher Education – Serbian Case," in *Procedia Computer Science*, vol. 126, pp. 1351–1359, 2018. https://doi.org/10.1016/j.procs.2018.08.086

[32] American Physical Therapy Association, *Guide to Physical Therapist Practice 3.0.* 2003.

[33] CL. Ventola, "Mobile Devices and Apps for Health Care Professionals: Uses and Benefits," *P T.*, vol. 39, no. 5, pp. 356–364, 2014.

[34] C. Fernández-Lao, I. Cantarero-Villanueva, N. Galiano-Castillo, E. Caro-Morán, L. Díaz-Rodríguez, and M. Arroyo-Morales, "The Effectiveness of a Mobile Application for the Development of Palpation and Ultrasound Imaging Skills to Supplement the Traditional Learning of Physiotherapy Students," *BMC Med Educ*, vol. 16, no. 1, p. 274, 2016. https://doi.org/10.1186/s12909-016-0775-1

[35] S. Clavijo-Buendía *et al.*, "Construct Validity and Test-Retest Reliability of a Free Mobile Application for Spatio-Temporal Gait Analysis in Parkinson's Disease Patients," *Gait Posture*, vol. 79, pp. 86–91, 2020. https://doi.org/10.1016/j.gaitpost.2020.04.004

[36] D. Cristina, A. Rodríguez, J. Nicolás, and C. Giaimo, "Use of Mobile Devices in Physiotherapy," *Revista Cubana de Información en Ciencias de la Salud (ACIMED)*, vol. 28, no. 2, pp. 1–13, 2017. Accessed: May 05, 2023. [Online]. Available: https://www.medigraphic.com/pdfs/acimed/aci-2017/aci172a.pdf

[37] T. Stütz *et al.*, "Mobile Phone–Supported Physiotherapy for Frozen Shoulder: Feasibility Assessment Based on a Usability Study," *JMIR Rehabil Assist Technol*, vol. 4, no. 2, p. e6, 2017. https://doi.org/10.2196/rehab.7085

[38] A. Razzaque, "M-Learning Improves Knowledge Sharing Over e-Learning Platforms to Build Higher Education Students' Social Capital," *Sage Open*, vol. 10, no. 2, 2020. https://doi.org/10.1177/2158244020926575

[39] I. Simonova and P. Poulova, "Learners Preferences in Mobile-Assisted Higher Education," *Procedia Computer Science*, vol. 104, pp. 174–182, 2017. https://doi.org/10.1016/j.procs.2017.01.099

[40] D. Smahel, S. Elavsky, and H. Machackova, "Functions of mHealth Applications: A User's Perspective," *Health Informatics J*, vol. 25, no. 3, pp. 1065–1075, 2019. https://doi.org/10.1177/1460458217740725

[41] T. Schwab and J. Langell, "Human Factors–Based Mobile Application Design for Global Health," *Surg Innov*, vol. 25, no. 6, pp. 557–562, 2018. https://doi.org/10.1177/1553350618814643

[42] P. Kruchten, "Architectural Blueprints-The '4+1' View Model of Software Architecture," in *IEEE Software*, vol. 12, no. 6, pp. 42–50, 1995. https://doi.org/10.1109/52.469759

[43] Sparx Systems, "Guide to the Trial Edition ENTERPRISE ARCHITECT User Guide Series," 2022.

[44] O. Levina, O. Holschke, and J. Rake-Revelant, "Extracting business logic from business process models," in *2010 2nd IEEE International Conference on Information Management and Engineering*, IEEE, pp. 289–293, 2010. https://doi.org/10.1109/ICIME.2010.5477554

[45] A. Muro-Culebras *et al.*, "Tools for evaluating the content, efficacy, and usability of mobile health apps according to the consensus-based standards for the selection of health measurement instruments: Systematic review," *JMIR mHealth and uHealth*, vol. 9, no. 12, p. e15433. https://doi.org/10.2196/15433

[46] T. Romero, C. Andrés, E. Gómez, and K. Andrea, "Algoritmo del 'juego de las equivalencias': Traducción de reglas desde lenguaje natural hacia pseudocódigo," *El Hombre y la Máquina*, vol. 35, pp. 161–165, 2010. [Online]. Available: http://www.redalyc.org/articulo.oa?id=47817140016

[47] L. Wang, W. Deng, H. Pan, and X. Deng, "Improved Evaluation Index Systems for Public Physical Education," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 3, pp. 154–170, 2021. https://doi.org/10.3991/ijet.v16i03.20473

[48] H. Lajane *et al.*, "Formative E-Assessment for Moroccan Polyvalent Nurses Training: Effects and Challenges: Case of the Higher Institute of Nursing and Health Techniques of Casablanca," *International Journal of Emerging Technologies in Learning*, vol. 15, no. 14, pp. 236–251, 2020. https://doi.org/10.3991/ijet.v15i14.13821

[49] Suyanta *et al.*, "Virtual Laboratory-Based Game Application: The Quality and Its Effects Towards Students' Motivation and Self-Regulated Learning," *International Journal of Interactive Mobile Technologies*, vol. 16, no. 18, pp. 114–132, 2022. https://doi.org/10.3991/ijim.v16i18.32875

[50] X. Liu, N. A. Samah, and S. M. Salleh, "The Impact of Using a Mobile App on Improving Students' Creative Thinking in Business English Writing with Self-regulated Learning," *International Journal of Interactive Mobile Technologies*, vol. 16, no. 15, pp. 46–61, 2022. https://doi.org/10.3991/ijim.v16i15.31477

[51] M. West, S. V. Vosloo, and R. Kraut, *Mobile Learning for Teachers: Global Themes*, 1st ed. Paris, 2012. Accessed: May 05, 2023. [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000216452

[52] A. Lagunes-Domínguez, C. A. Torres-Gastelú, J. Angulo-Armenta, and M. Á. Martínez-Olea, "Prospectiva hacia el Aprendizaje Móvil en Estudiantes Universitarios," *Formación Universitaria*, vol. 10, no. 1, pp. 101–108, 2017. https://doi.org/10.4067/S0718-50062017000100011

[53] S. Lam and W. Chung, "Uses of Internet and Mobile Technology in Health Systems for the Elderly: A Case Study of Hong Kong," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 4, no. 2, p. 40, 2010. https://doi.org/10.3991/ijim.v4i2.1175

[54] S. Karim and E. Gide, "The Use of Interactive Mobile Technology to Improve the Quality of Health Care Services in Private and Public Hospitals in Australia," *International Journal of Interactive Mobile Technologies*, vol. 12, no. 6, pp. 4–18, 2018. https://doi.org/10.3991/ijim.v12i6.9204

10 AUTHORS

Carlos Andrés Tavera Romero is currently a full-time Professor at the Faculty of Engineering, Santiago de Cali University. He is the coordinator of the research line for Computer Systems Development of the COMBA R&D research group. His research interest includes information systems development, information technologies and software engineering. (E-mail: carlos.tavera00@usc.edu.co)

Jennifer Jaramillo Losada is a full-time Professor in Physiotherapy at the Faculty of Health, Santiago de Cali University. Her research interest includes physiotherapy and gerontology. She is currently a researcher in the Health and Movement research group. (E-mail: Jennifer.jaramillo01@usc.edu.co)

María Fernanda Díaz Velásquez is a full-time Professor of the Electronic Engineering program and a researcher in GIEIAM research group at the Faculty of Engineering, Santiago de Cali University (E-mail: maria.diaz20@usc.edu.co).

Andrés Gerardo Domínguez Pineda is a systems engineer and research assistant for the COMBA R&D research group at the Faculty of Engineering, Santiago de Cali University (E-mail: andres.dominguez00@usc.edu.co).

Victor Manuel Hurtado López is a systems engineer and research assistant for the COMBA R&D research group at the Faculty of Engineering, Santiago de Cali University (E-mail: victor.hurtado02@usc.edu.co).