

# Co-Designed Collaborative Digital Platform for Early Childhood Development: An Innovative Web and Mobile Application for Practitioners and Guardians

Plataforma digital colaborativa co-diseñada para el desarrollo infantil temprano: integrando a profesionales y familias mediante una aplicación web y móvil



**Dr. Achilleas Achilleos**

Lecturer at the Department of Computer Science and Engineering, Frederick University, Cyprus



**Dra. Aleksandra Karovska Ristovska**

Institute for Special Education and Rehabilitation, University Ss. Cyril and Methodius.



**Dr. Christos Markides**

Department of Electrical Engineering, Computer Engineering and Informatics, Frederick University Cyprus, Cyprus



**Dr. Savvas Pericleous**

Assistant Professor at the Department of Electrical and Computer Engineering and Informatics at Frederick University, Cyprus

## ABSTRACT

**Introduction:** The UPDEIT EU-funded project addresses the need for improved digital solutions in Early Childhood Development and Intervention (ECDI) by offering a more collaborative platform than existing applications. Its contribution lies in the design and development of a **progressive web application (PWA) that can be used either as a web platform or a mobile application**, facilitating real-time collaboration between practitioners (i.e., developmental specialists) and guardians.

**Methodology:** Using a **co-creation approach**, the research team first collected qualitative data to identify user needs for offering the required ECDI features, focusing on providing collaborative features and dual-platform accessibility. These insights guided the iterative development of the web platform and PWA, which were evaluated via the **quantitative User Experience Questionnaire (UEQ)**.

**Results:** Findings indicate that the platform performs strongly in **stimulation, attractiveness, and dependability**, underscoring its potential to engage and support users effectively. However, **perspicuity and efficiency** emerged as areas requiring further refinement to improve user experience and functionality.

**Discussion:** By developing a PWA, UPDEIT advances collaborative ECDI practices and sets a precedent for future digital health interventions. The outcomes of this work provide actionable guidelines for enhancing collaboration, accessibility and inclusive design in early intervention services.

## RESUMEN

**Introducción:** El proyecto UPDEIT, financiado por la UE, responde a la necesidad de mejorar las soluciones digitales en desarrollo e intervención en la primera infancia (ECDI) al ofrecer una plataforma más colaborativa que las aplicaciones existentes. Su aportación radica en el diseño y desarrollo de una aplicación web progresiva (PWA) que puede usarse como plataforma web o como aplicación móvil, facilitando la colaboración en tiempo real entre profesionales (especialistas en desarrollo) y tutores.

**Metodología:** Mediante un enfoque de cocreación, el equipo de investigación recopiló primero datos cualitativos para identificar las necesidades de los usuarios y ofrecer las funcionalidades ECDI requeridas, con especial atención a las características colaborativas y al acceso dual a través de web y móvil. Estos hallazgos guiaron el desarrollo iterativo de la plataforma web y de la PWA, que se evaluaron mediante el Cuestionario de Experiencia de Usuario (UEQ).

**Resultados:** Los resultados indican que la plataforma destaca en estimulación, atractivo y fiabilidad, lo que subraya su capacidad para involucrar y apoyar a los usuarios de manera eficaz. Sin embargo, perspicuidad y eficiencia surgieron como áreas que requieren ajustes adicionales para mejorar la experiencia y la funcionalidad.

**Discusión:** Al desarrollar una PWA, UPDEIT impulsa las prácticas colaborativas en ECDI y sienta un precedente para futuras intervenciones digitales en salud. Los resultados de este trabajo ofrecen pautas prácticas para mejorar la colaboración, la accesibilidad y el diseño inclusivo en los servicios de intervención temprana.

## KEYWORDS -PALABRAS CLAVES

early intervention, digital tools, universal design, collaboration, developmental specialists, user experience, usability evaluation, accessibility, inclusive design

Intervención temprana, herramientas digitales, colaboración, accesibilidad, experiencia del usuario, cuestionario UEQ, diseño inclusivo, evaluación de usabilidad

## 1. Introduction

The rapid advancement of digital technologies has propelled significant shifts in educational paradigms thus presenting transformative possibilities for enhancing pedagogical practices and learning outcomes. Tools such as mobile applications, telehealth platforms, and machine learning algorithms are now used to deliver real-time feedback, facilitate remote interventions, and personalize educational content to meet diverse learner needs. Digital technologies are not only instrumental for improving existing educational methods, but they also redefine pedagogical structures and the overarching goals of modern education (Haleem et al., 2022; Lindín et al., 2023).

Early Childhood Development and Intervention, a field dedicated to addressing developmental delays and disabilities in young children, has particularly benefited from these technological advancements (Hatzigianni et al., 2023, Wyeth et. al., 2023). By grasping innovations such as artificial intelligence, machine learning, and mobile health technologies, ECDI practitioners (i.e., developmental specialists) now have the tools that facilitate real-time developmental assessments and personalized intervention strategies.

Empirical evidence highlights the central role of ECDI in mitigating developmental delays, with long-term benefits that include improved cognitive and social outcomes for children, enhanced family well-being, and reduced societal costs through decreased need for specialized services later in life (Guralnick, 2011; Halpin et al., 2024, UNICEF, 2023). Camden and Silva (2021) highlight the rapid adoption of telehealth in pediatric therapy during the COVID-19 pandemic, demonstrating its effectiveness in supporting families of children with disabilities. Telehealth strategies like videoconferencing and online programs allow therapists to tailor interventions to each child's environment. While families report benefits such as improved communication and accessibility, they also face challenges like limited access to technology (Yang et al., 2021).

However, persistent disparities in access to trained professionals and validated resources affirms the need for more innovative solutions (WHO & UNICEF, 2012). These challenges can be addressed by the creation of digital platforms to enable wider access to high-quality ECI resources. The Erasmus+ project UPDEIT (UPDating university curricula on Early InTervention) represents such a crucial intervention aimed at bridging critical gaps in accessible and evidence-based resources for ECDI across Europe. This initiative emphasises the merging of technological innovation, ECDI and inclusive education by fostering the creation of digital tools and curriculum frameworks designed to strengthen professional competencies and expand the outreach of intervention services.

The UPDEIT project focuses on integrating digital tools such as the milestone-tracking mobile application and web-based Open Educational Resources (OER) to redefine how early intervention resources are accessed and utilized, promoting both innovation and inclusivity in educational practices. Aligned with global priorities for digital transformation in education defined by UNESCO (2022), UPDEIT emphasizes competency-based learning and stands by the principles of Universal Design for Learning (Meyer et al., 2014). These principles are operationalized within the UPDEIT app by offering multiple means of representation, such as visual and audio resources to convey developmental milestones, multiple means of action through interactive features for tracking progress, and multiple means of engagement by gamifying certain tasks to sustain user interest and motivation. These frameworks ensure that the projects' resources are inclusive and adaptable, meeting the diverse needs of learners across contexts. Furthermore, the project's transnational collaboration among higher education institutions fosters a dynamic exchange of expertise,

promoting best practices and cultivating a workforce equipped to support children with developmental challenges.

This paper examines the objectives, methodologies, and innovative outcomes of the UPDEIT project, situating its contributions within the broader discourse on digital and inclusive education.

## 2. Related Work

### 2.1. Research studies

Early identification of developmental delays has a pivotal role in shaping long-term positive outcomes for children. In order to identify early these development delays, it is important and necessary to employ standardized screening tools and assessments that are grounded in evidence-based research. Furthermore, it is important to adopt empirically validated strategies for supporting children exhibiting delays. Therefore, in the era driven by technological innovation it is paramount to create intuitive, simple and creative digital platforms and tools that are grounded on evidence-based research to facilitate tracking early childhood developmental delays and apply suitable intervention strategies.

Relevant research works have been involved with the advancement of early childhood development and intervention practices, as well as implemented digital tools to support practitioners (i.e., developmental specialists) in this process. Foremost, the research work presented in (Almeqdad et. al., 2023, IDA, 2021), provides a comprehensive synthesis of how Universal Design for Learning (UDL) principles are being applied in diverse educational settings. The authors examine empirical studies focusing on teacher preparation, instructional strategies and technology integration to support learners with varying needs. Their findings emphasize the significance of digital tools, such as interactive applications and online learning modules, to present content in multiple formats and to foster active engagement. This research is highly relevant to UPDEIT's approach, as it underscores the importance of varied representations, actions, and engagement strategies to ensure inclusivity. This is fundamental since these principles have been applied in the development of the web platform and mobile application presented in this work.

Tim Brown's IDEO framework (Brown, 2008) is a human-centered, iterative process with three overlapping phases: 1) Inspiration (empathize and define), 2) Ideation (generate and prototype) and 3) Implementation (test and refine). It leverages ethnographic research, rapid prototyping, and multidisciplinary collaboration to ensure solutions meet real user needs. IDEO is widely adopted across sectors, it drives innovation by continually cycling feedback into product and process improvements.

In a research study (Chatzigeorgiadou et. al., 2022) applied the IDEO<sup>1</sup> design thinking framework to deepen young learners' understanding of the water cycle by integrating digital tools. This included tools such as concept-mapping software, simulations and interactive whiteboards, within a structured empathize–define–ideate–prototype–test sequence. Sixty-one kindergarten children (mean age 5.2 years) engaged actively in each phase, producing drawings, concept maps and verbal explanations that documented their evolving scientific concepts. Teachers' reflective diaries and digital recordings captured how iterative

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<sup>1</sup> IDEO: 40+ years of design & innovation – <https://www.ideo.com/about>

prototyping and feedback, supported by immersive digital technologies, scaffolded children's inquiry, fostered collaboration and yielded demonstrable gains in water-cycle literacy. The study underscores the efficacy of combining design thinking with interactive digital resources to promote inquiry-based science learning in early childhood settings and calls for further research to extend this pedagogical synergy.

Moreover, the authors of another study conducted a qualitative, descriptive study to identify the core features that early childhood educators require in mobile learning applications (Boude Figueredo et. al., 2024). Engaging preschool teachers from the Universidad de La Sabana and following the Mobile-D agile development methodology, they pinpointed essential design elements, such as intuitive navigation, multimodal content presentation, real-time progress tracking, and culturally responsive feedback loops. These essential design elements strengthen children's cognitive, motor, communicative, and aesthetic development. Their findings directly informed the creation of a prototype mobile application demonstrably more effective than generic store-bought educational tools at supporting holistic early learning in classroom settings.

Additional research work discusses the evolution and current best practices of authentic assessments in early childhood special education settings (Bagnato et. al, 2024, Zyskind & Macy, 2024). The assessment model proposed in this work revolves around collaborative, play-based approaches that capture a child's development in a real-life context. Although this work does not refer to the implementation of digital tools for early childhood screening, this research work highlights the growing role of technology-enhanced tools (e.g., tablet-based observations and data analytics). Specifically, the work outlines and emphasizes the importance of technology in simplifying data collection and fostering collaborative decision-making among educators and families. The key insights revealed by the results align fully with the milestone-tracking and progress-monitoring elements of the work presented in this paper, which similarly leverage technology for more accurate and holistic assessments.

In another research work that is directly relevant, the authors examine how gamification within mobile applications can advance motivation, adherence, and learning outcomes for children in early intervention programs (Kakoura et. al., 2024, Mahmoudi et. al., 2024). The study provides evidence collected from a variety of digital platforms, which highlight that feature such as rewards, progress tracking, and interactive feedback loops are important in sustaining engagement in this process. The results of this work reveal that research backed gamified systems can positively impact developmental outcomes across motor, cognitive, and social domains. This work provides empirical backing for incorporating gamification strategies into its app to improve user engagement and track child development milestones effectively.

Finally, it is important to note that children are the basis for all dimensions of sustainable development. In the Global Sustainable Development Report (GSDR Brief, 2015) brief by the Thematic Group on Early Childhood Development, Education and Transition to Work emphasizes that children's early health, learning and social environments are foundational to sustainable development, impacting long-term cognitive, social and economic outcomes. Drawing on decades of evidence, it demonstrates that investments in proven ECDI interventions, such as quality pre-primary education, nutrition and stimulation programs, yield high returns in schooling completion, earnings, and societal well-being. The brief calls for including age-disaggregated indicators under SDG monitoring frameworks to ensure that early childhood remains central to global development policies.

## 2.2. Mobile Applications

Different efforts have been made towards developing mobile applications, to assist parents and practitioners in tracking early childhood development and providing intervention. These tools focus on ECDI, but lack in terms of providing the technical capabilities for parents/guardians to collaborate in real time with practitioners. Moreover, they do not provide customised and personalised user interfaces that enable them to work on different devices and platforms.

The Centers for Disease Control and Prevention (CDC) offer the Milestone Tracker (Milestone Tracker App, 2025), which is a free and evidence-based mobile application designed to help parents and caregivers monitor their child's developmental milestones from two months to five years of age. The application includes illustrated checklists and recommendations for healthy development, as well as alerts to encourage parents and their families to share any concerns with healthcare providers. The application provides a user-friendly interface and translation functionalities, which makes it accessible to diverse populations. This aligns closely with UPDEIT's goal of promoting inclusivity and widespread adoption of early intervention resources.

Another mobile application is BabySparks (BabySparks, 2025), which is commercially available and offers personalized activity programs and milestone tracking for children aged 0–3. The activities offered within the application are supported by expert guidance and aim to help the parents detect early childhood development problems and at improving cognitive, motor, social and emotional skills. This application provides personalised recommendations based on the user's input over time, thus providing adaptive behaviour and tailored experience in accordance with the child's development trajectory. It thus reflects the personalized approach at the core of the UPDEIT project, enabling the diverse needs of learners to be met through flexible, technology-driven solutions.

The next mobile application is Sparkler (Sparkler, 2025), which is more closely related to the UPDEIT mobile application and platform. It is a research-driven mobile application that blends developmental screening, milestone tracking, and curated learning activities. It is designed for parents, caregivers, and educators. The application provides questionnaires, such as the ages and stages questionnaires, which aim at identifying children's strengths and areas that require the parents' attention, support and developmental practices. It offers several interactive and gamified activities and provides a real-time feedback loop based on data driven insights. Also, the Sparkler application fits the aims of the UPDEIT work, which is to provide comprehensive resources that encourage consistent monitoring and tailored interventions.

The Care2Learn mobile app offers a collaborative, role-based environment where parents, caregivers and practitioners can jointly monitor and support children's development in real time (Care2Learn Consortium, 2021-2024). It features customizable developmental checklists, secure messaging for instant feedback, and data-driven dashboards that adapt to each child's learning profile across web and mobile interfaces. By integrating synchronous collaboration tools, offline data capture and automated progress reporting, Care2Learn addresses gaps in existing ECDI apps by ensuring that both practitioners and guardians contribute to a unified, continuously updated intervention plan.

Kinedu is a commercially available early childhood development app that offers personalized activity plans, milestone tracking, and two-way messaging between parents and practitioners (Kinedu, 2025). Leveraging expert-curated content and growth analytics,

Kinedu guides caregivers through daily, age-appropriate exercises designed to foster cognitive, motor, and socio-emotional skills. While its evidence-based interventions closely align with UPDEIT's research-driven objectives, Kinedu does not currently support a real-time, collaborative co-design environment for multiple stakeholders to jointly monitor progress and adjust intervention strategies.

Otsimo is a platform targeting children with special educational needs, featuring gamified exercises, progress dashboards, and customizable difficulty levels to promote engagement and skill acquisition (Otsimo, 2025). The app provides detailed parental summaries and data-driven insights into each child's learning trajectory, ensuring activities adapt to individual strengths and challenges. Although Otsimo's focus on adaptivity and inclusivity resonates with UPDEIT's goals, it lacks built-in collaborative goal-setting and synchronous multi-user monitoring tools that enable guardians and practitioners to co-manage interventions in real time.

Overall, the above solutions highlight the increasing role of technology in ECDI. However, none fully integrates a collaborative framework where both practitioners and guardians actively track, evaluate and intervene in a child's developmental progress in real-time. Moreover, our solution, in contrast to these mobile applications, offers a progressive web application (PWA) that can be used either as a web platform on a desktop/laptop device or a mobile application on a smartphone/tablet device. The UPDEIT PWA offers a comprehensive, research-based, and collaborative approach to early childhood intervention.

## 2.3. UPDEIT contributions

This work builds on the above research studies and commercial mobile applications, while it provides three additional functionalities that are the main contributions of this work:

- **Integration of UDL Principles in ECDI:** Building on previous research finding the UPDEIT project focuses on the development and integration of digital tools such as the milestone-tracking mobile application with the developed OERs and intervention instruments to redefine how early intervention resources are accessed and utilized, promoting both innovation and inclusivity in educational practices, as well as their use within the mobile application for early childhood intervention.
- **Collaborative Platform for Practitioners and Parents:** The key innovation is the mobile application that is designed, developed and can be used by both the parents and the healthcare practitioners (i.e., ECDI developmental specialists). It thus provides direct communication, data exchange and analysis between the parents and the healthcare practitioners, to collaborate fully, enable and support early childhood developmental delays detection and provide research-based intervention.
- **A Multi-Platform, Mobile-First Progressive Web Application:** On the technology side and compared to mobile applications presented in Section 2.2, the UPDEIT tool is a mobile first web-based application that can be used on any device, i.e., smartphone, tablet, laptop, desktop, and platform according to the preferences of the user and the settings under which the application is used, e.g., at home by parents, at the office by the healthcare practitioner.

### 3. The UPDEIT System

#### 3.1. Overview

The system analysed, designed and implemented in this work is a comprehensive web-based platform and progressive web application (PWA) designed for early childhood intervention. It provides an integrated environment where healthcare practitioners can assign activities, conduct evaluations, and monitor child development, while parents and/or guardians can track their child's progress, receive personalized recommendations, and access intervention resources. The platform is designed to be multilingual, GDPR-compliant, and accessible across multiple devices, ensuring inclusivity and scalability. With its structured milestone tracking and interactive assessment tools, the system enhances collaboration between practitioners and parents, ultimately supporting early childhood development through technology-enhanced interventions. Finally, the platform includes open educational resources for parents and/or guardians.

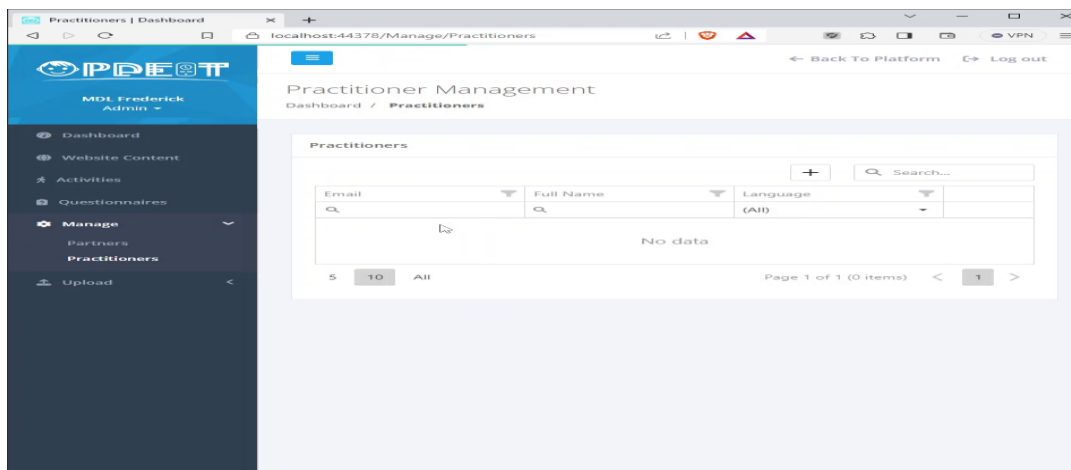
#### 3.2. Key Technology Features

##### 3.2.1. User Management and Multi-Role Support

The UPDEIT system offers robust user management features, catering to multiple user roles, including guardians, practitioners, and administrators. Each role has tailored functionalities, ensuring secure and efficient access to relevant features. **Figure 1** showcases the user interface when the administrator is logged in and specifically it demonstrates how the administrator can add, edit and remove practitioners to the platform.

**Figure 1**

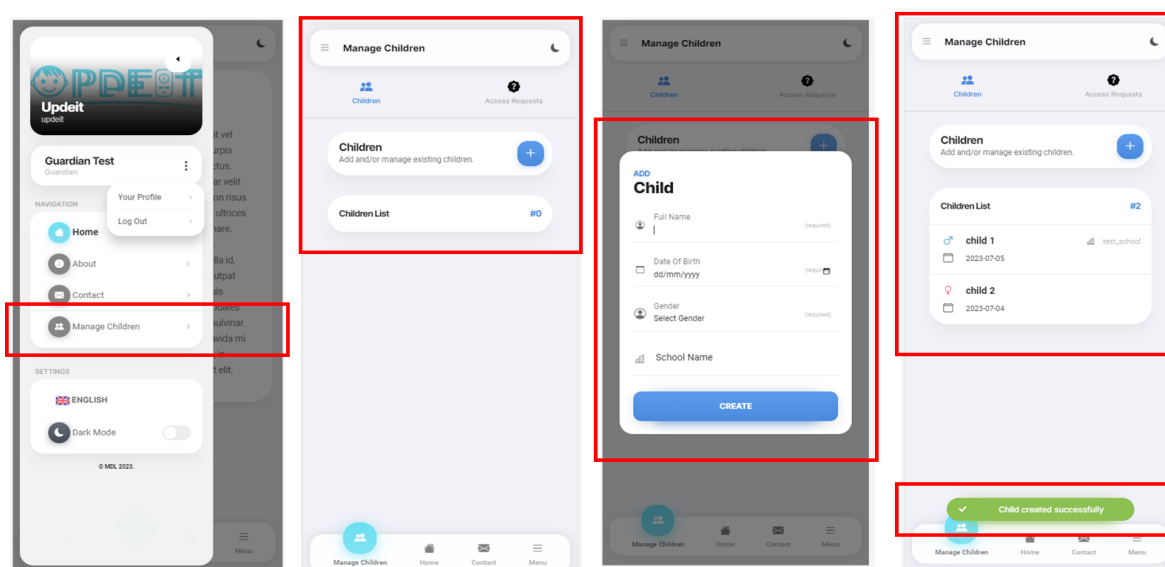
*The Web Platform UI: Main Dashboard and Adding Practitioners*



The parents and/or guardians can use the application to manage, track and monitor their children's early childhood development progress. Initially, they can register their children, monitor developmental milestones and interact with assigned activities. **Figure 2** showcases the user interfaces that parents can use to manage the children under their care.

**Figure 2**

*The Mobile Application UI: Managing Children Process*



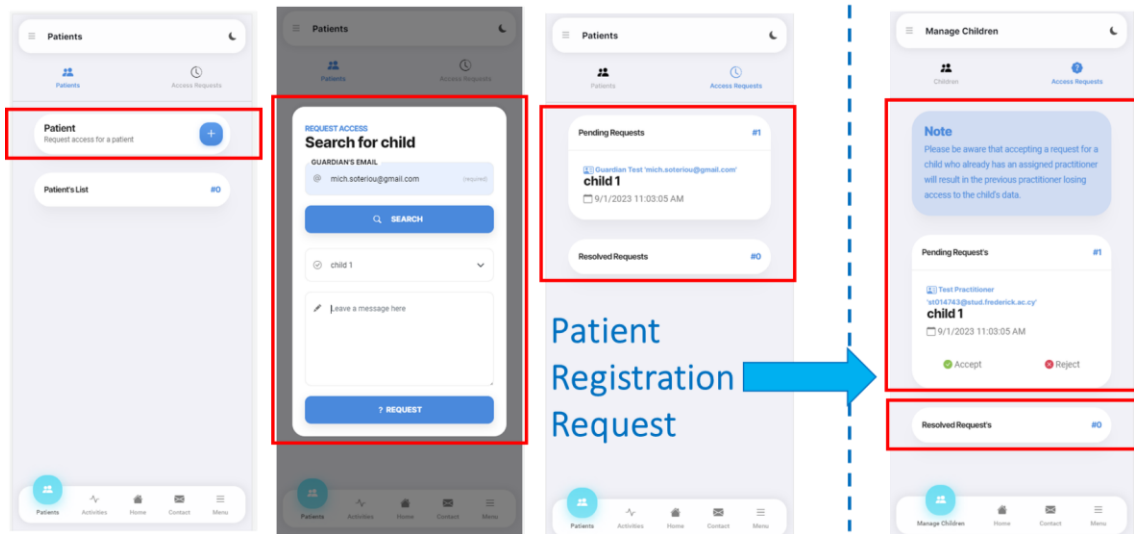
The parent can first add one or more children using the web application. It is important to note once again that all users of the web application can use it on a smartphone, tablet, laptop or any other device. For instance, adding a child can even be done from their smartphone, while if they want to have a look at the activities assigned by the practitioner or the results of the practitioner's evaluation questionnaires in a more detailed way, they can open the web application on their desktop or laptop device.

### 3.2.2. Early Childhood Development Evaluations

The web application enables practitioners to manage patients by searching for children already registered in the system using their parents' email addresses, when they visit the practitioner for the first time. This is to ensure that the practitioners have access to a child's data only if they obtain the parents' approval, which is given by the parent by disclosing his/her email address. Subsequently, the parents and/or guardians need to approve the practitioner's request for accessing the child's information and health data. The parent has the capability to revoke access at any time, e.g., if he/she decides to go to another practitioner. The process is displayed in the sequence below (see **Figure 3**).

**Figure 3**

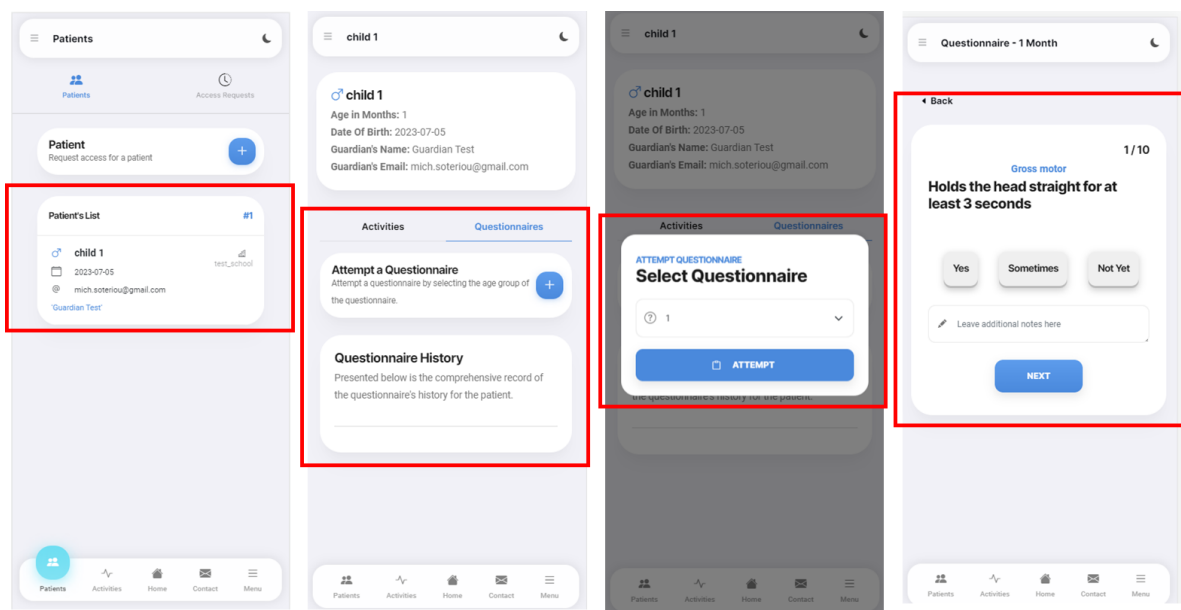
*The Mobile Application UI: Child Registration Request and Approval Process*



As soon as the parent accepts the request of the practitioner the child is moved to the Resolved requests of the practitioner and under his/her care (see Figure 4). The practitioner can then see the child's profile and can track, monitor and evaluate the child's progress. At the first session, the practitioner conducts an early childhood development evaluation. The practitioner can assess the child's developmental status using evaluation instruments in the form of questionnaires that were defined in the UPDEIT project and based on the research performed. The process below showcases how an evaluation can be performed.

**Figure 4**

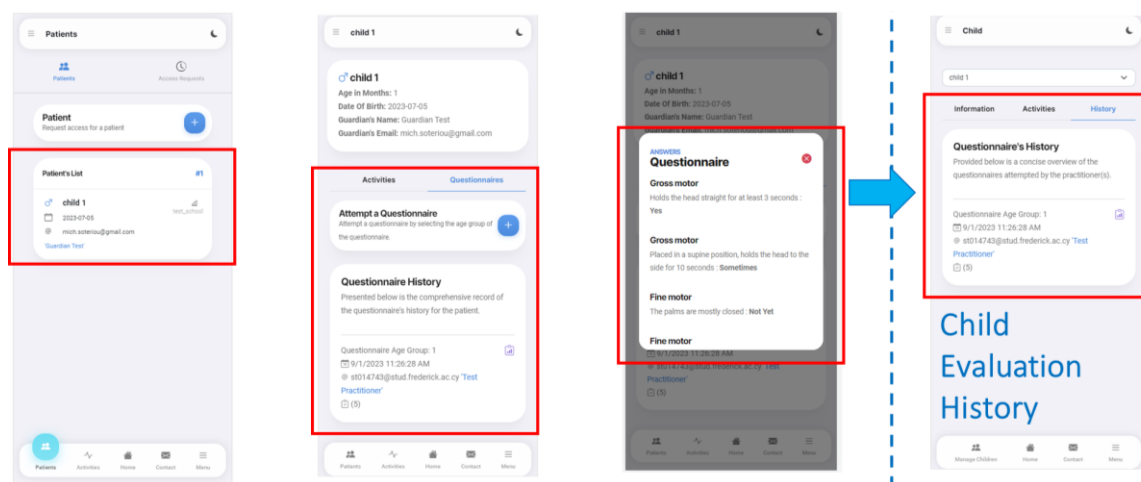
*The Mobile Application UI: Child Developmental Evaluation Process*



Overall, practitioners can continue to conduct evaluations using questionnaires and observational data, with results stored securely for tracking and analysis. This allows the practitioner to start off and continue to evaluate the child over different sessions, since the web application allows keeping an evaluation history for each child. Specifically, the practitioner responsible can evaluate the child with every visit and keep a record of the child's progress. **Figure 5** showcases how the practitioner can access the child's evaluation history, while the screenshots above indicate an empty history during the first evaluation.

**Figure 5**

*The Mobile Application UI: Child Evaluation History*

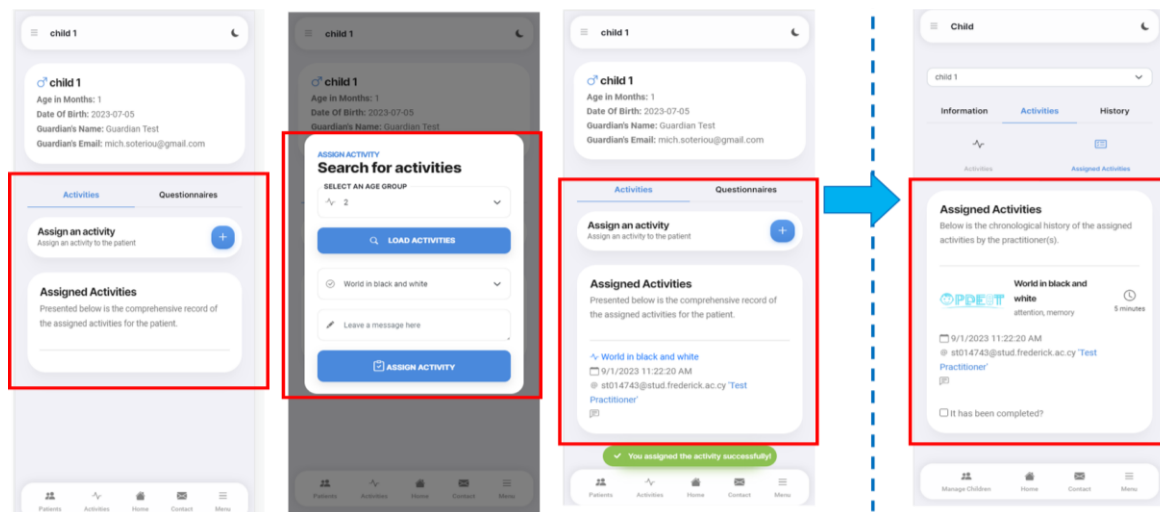


### 3.2.3. Early Childhood Development Interactive Activities

Following the developmental evaluation, the practitioner responsible for the child's evaluation is then able to assign personalised and customisable activities based on the child's age and specific requirements, to help and support the child's development progress. The parents can then see these activities (see Figure 6) and can perform them with the child from the comfort of their own home until the next visit to the practitioner. The developmental interactive activities are also founded on research-based outcomes, and they were defined as part of the UPDEIT project. They are structured based on age groups/ranges, and they are defined based on play-based learning approaches and evidence-based intervention strategies. It is important to highlight that the web application includes interactive content, such as images and videos, to enhance user engagement. The evaluation instruments and the interactive activities allow both the practitioner and the parent to assess, monitor and track the child's development in a fully collaborative manner. This is the key contribution presented in this paper, since the UPDEIT web application is to the best of our knowledge the only one that offers this collaborative feature.

**Figure 6**

*The Mobile Application UI: Assign Interactive Activities*



To better highlight the **key contribution** of this work—namely, the **collaborative platform** available to practitioners and parents—it is important to note the following. The practitioner can assign activities to be completed within a specific timeframe (e.g., two months), and the parent or guardian can then view these activities through **text, images, or videos** in the platform. This setup ensures that the child can engage with targeted exercises at home, with clear instructions on how to perform them.

Subsequently, during a follow-up visit, the **practitioner re-evaluates** the child's performance and, in collaboration with the parent or guardian, decides whether to continue with the same activities or assign new ones. This process allows for **ongoing tracking of the child's development** and offers a structured way to adjust interventions as needed. By keeping a detailed history of completed exercises and progress, the platform supports **personalized and continuous** early childhood intervention.

### 3.2.4. Data Tracking and Export Capabilities

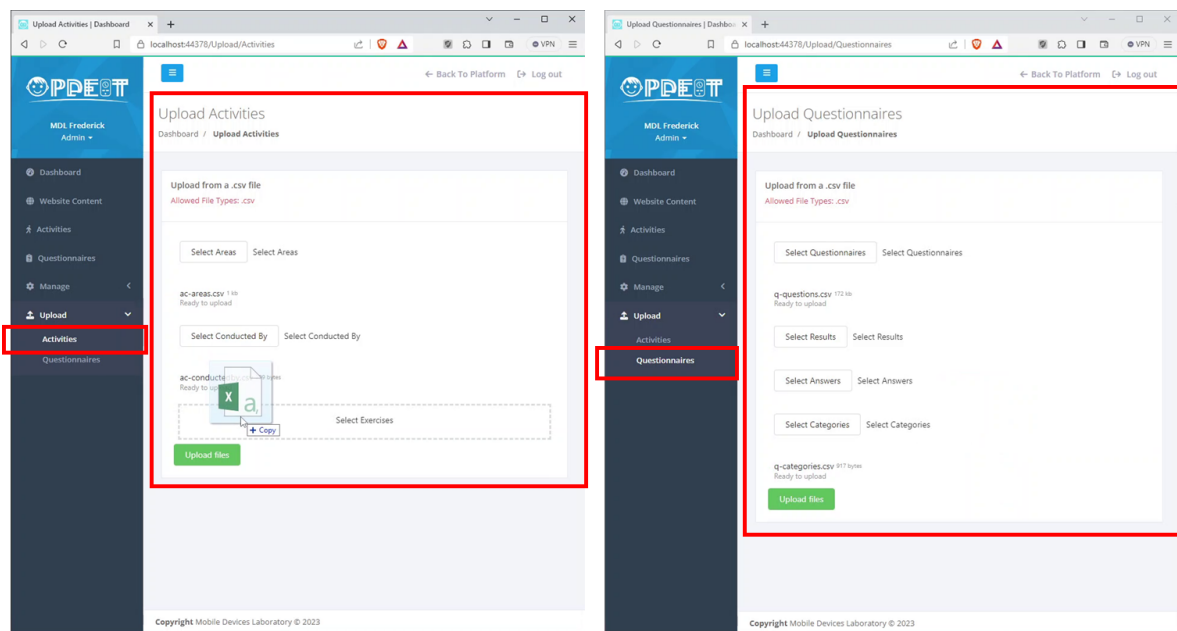
The UPDEIT web application provides a structured and efficient way to upload early childhood development activities that children can perform with their parents. Practitioners can seamlessly upload activities in bulk using CSV files, ensuring that age-appropriate exercises are assigned systematically (**see Figure 7**). The platform supports categorization by developmental areas and allows practitioners to specify who will conduct the activities. This feature ensures that activities align with developmental milestones, engaging parents in the intervention process while enabling structured tracking of progress over time. Additionally, the system allows for appending new activities to existing sets, making it adaptable to evolving research and intervention strategies.

Beyond activity management, the platform facilitates the upload and organization of evaluation questionnaires for assessing a child's developmental status (**see Figure 7**). Practitioners can import questionnaires via CSV files, categorizing them by question type, expected results, and answers. This structured approach ensures that assessments remain

standardized while allowing flexibility to include new screening tools as needed. Questionnaires can be assigned based on age groups, ensuring tailored evaluations that align with developmental expectations. The system's ability to maintain a comprehensive record of completed assessments further enhances early intervention efforts, allowing for data-driven decision-making and continuous monitoring of a child's progress.

**Figure 7**

*The Mobile Application UI: Data Management*



Another key component of the UPDEIT system is its ability to track assigned activities and evaluation results. Data is stored in a structured format that supports filtering, searching, and exporting. Practitioners can generate reports in Excel format, allowing them to analyze trends over time. The system ensures data privacy and compliance with GDPR regulations, making it a reliable tool for professionals and researchers.

### 3.3. System Technologies

The UPDEIT platform is implemented as a Progressive Web Application (PWA), a modern web-based solution that combines the best features of both web and mobile applications. A PWA provides a responsive, fast, and reliable user experience across multiple devices, including smartphones, tablets, and desktops, without requiring installation from an app store. It achieves this by leveraging service workers for offline functionality, responsive design to adapt seamlessly to different screen sizes, and web app manifests that allow users to install the platform as an app-like experience directly from their browser. By using PWA technology, UPDEIT ensures accessibility and usability across various operating systems while maintaining a lightweight, efficient application.

The backend of the system is built using the .NET framework, a robust and scalable development platform that supports web services and enterprise-grade applications. It

integrates a secure Content Management System (CMS) to facilitate structured content delivery and manage resources such as activities, questionnaires, and user profiles. A relational database is implemented to store and manage structured data, ensuring data integrity, efficient retrieval, and compliance with GDPR regulations. The backend also supports role-based access control (RBAC), allowing different user roles—such as practitioners, parents, and administrators—to access functionalities tailored to their specific needs.

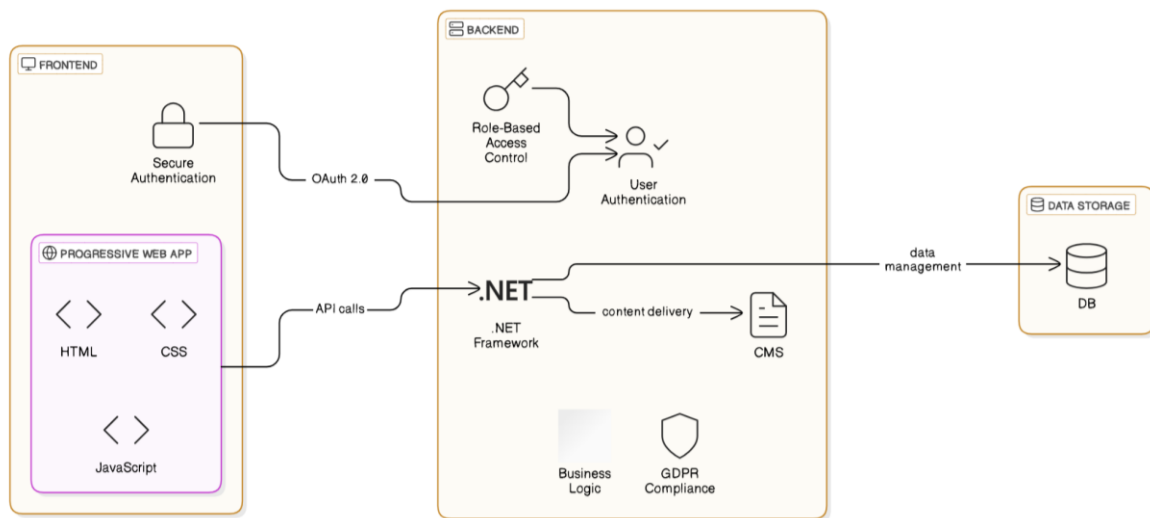
On the front-end, the platform utilizes HTML, CSS, and JavaScript, enabling an interactive and user-friendly interface. These technologies ensure that the system is not only visually engaging but also highly responsive, providing smooth navigation and dynamic content rendering. JavaScript frameworks and libraries further enhance the interactivity of the application, allowing real-time updates and seamless communication with the backend. Additionally, the UPDEIT platform integrates secure authentication mechanisms, such as OAuth 2.0 or multi-factor authentication, to safeguard user data and ensure that only authorized users can access sensitive information. This combination of modern web technologies, security features, and cross-platform compatibility makes the UPDEIT platform a powerful and scalable tool for early childhood intervention.

### 3.4. UPDEIT Web Application Architecture

The UPDEIT platform follows a client-server model, where the PWA operates as the client interface, interacting with the backend services through API calls. The backend, developed in .NET, handles business logic, user authentication, and data management. The database stores user profiles, assigned activities, evaluation results, and reports. This architecture ensures seamless synchronization across devices while maintaining high performance and security. The platform architecture is depicted in **Figure 8**.

**Figure 8**

*The UPDEIT platform architecture*



Furthermore, the platform is designed and developed taking into consideration all necessary scalability and security aspects. The system is designed to be scalable, accommodating a growing number of users and datasets. The database schema supports structured milestone tracking, while cloud-based hosting ensures accessibility and redundancy. Security is a priority, with GDPR compliance, encrypted data transmission, and role-based access control (RBAC) implemented to protect sensitive user data. The progressive web application architecture allows offline access to certain features, ensuring usability even in low-connectivity environments.

## 4. Evaluation

### 4.1. Methodology

The evaluation was conducted using the **User Experience Questionnaire (UEQ)** (Laugwitz et. al., 2008), drawing participants from three different countries (Spain, Cyprus and North Macedonia). A total of 70 participants were involved in the study across the three countries. Specifically, 47 participants from Spain, 12 participants from Cyprus and 11 participants were from North Macedonia. This distribution reflects the collaborative, multi-national nature of the project and ensures that perspectives from diverse early childhood development contexts are represented in the evaluation of the platform. Each participant was asked to log into the platform either in the role of a practitioner or a guardian/parent. By distributing these roles across diverse regions, the evaluation aimed to capture a broader perspective on the platform's usability and functionality.

In our study, the sampling was based on convenience and availability of participants from partner organizations involved in the co-design and evaluation of the platform across three countries. While this approach allowed us to gather diverse user feedback within the scope and timeline of the project, we acknowledge that it limits the generalizability of the

findings and may introduce selection bias. The study has been conducted in a period of two months as defined in the pilots of the project. Moreover, the User Experience Questionnaire (UEQ) was selected due to its established validity, reliability and suitability for evaluating interactive systems in a cross-cultural context. The UEQ offers a well-balanced structure that captures both pragmatic and hedonic qualities of user experience, making it appropriate for assessing the usability and engagement of participants with the mobile application.

To measure how well the platform aligned with user needs, we designed specific tasks for each user role. Practitioners were instructed to add children to the system, perform developmental evaluations, assign activities for guardians/parents to complete, and subsequently review the child's developmental history. Guardians/parents, on the other hand, confirmed access requests from the practitioners, checked the assigned activities to ensure they were displayed clearly, and examined the child's developmental history after logging in. Once participants completed these tasks, they filled out the UEQ via Google Forms to share feedback on the platform's overall experience, offering insights into its usability, clarity, and reliability.

In the UEQ, each dimension—such as attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty—is evaluated based on a set of contrasting adjective pairs, typically initially rated by participants for each item on a 1–7 scale. These raw ratings are then linearly transformed to the questionnaire's standard scale, which ranges from -3 (most negative) to +3 (most positive). This transformation ensures that the final scores for each dimension (e.g., attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty) can be interpreted consistently and compared against benchmark data. By averaging each participant's transformed scores across all relevant items, researchers obtain a single numeric value per dimension, allowing them to pinpoint the application's strengths and weaknesses in a clear, standardized way.

## 4.2. Demographics

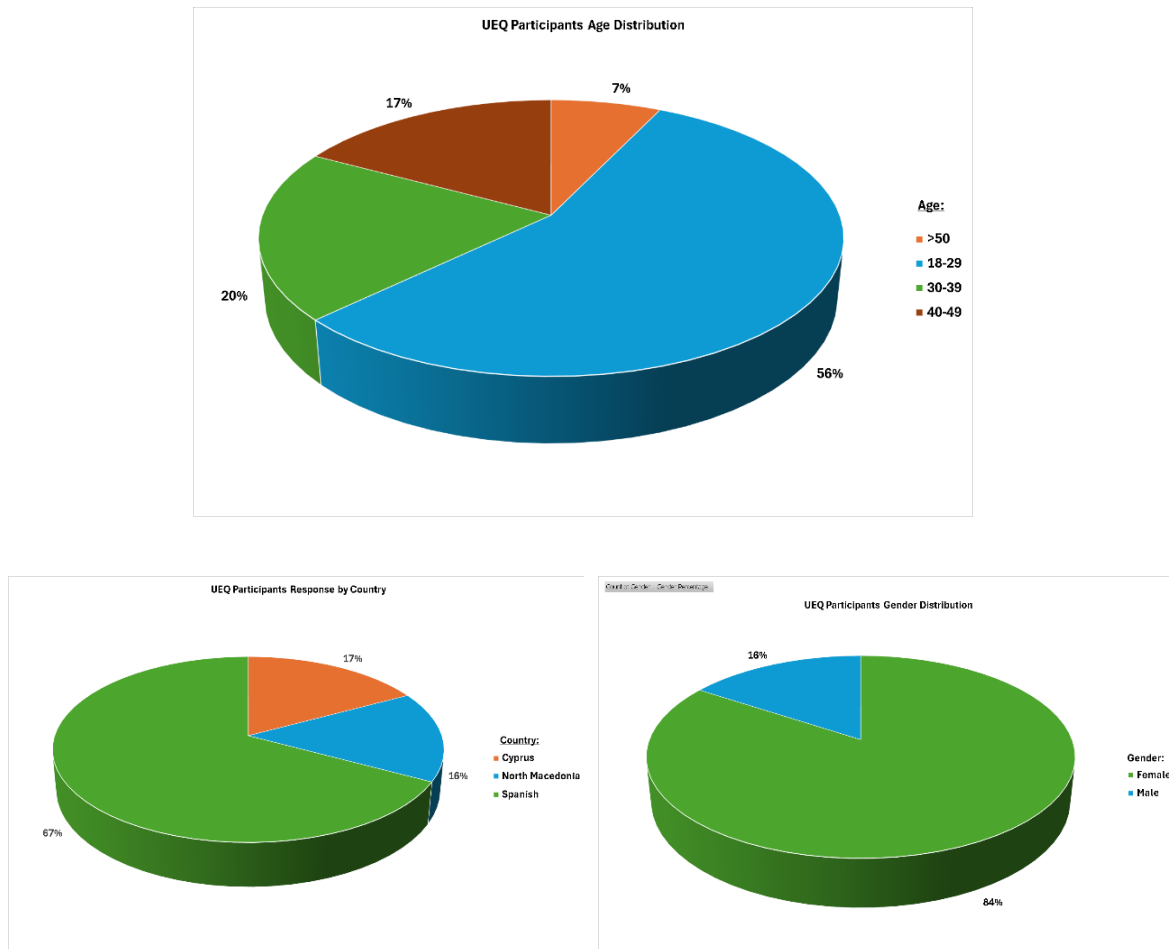
The study's detailed demographic data is captured in **Figure 9**. The participant group in this study consisted of 70 individuals, predominantly female (84% - 59 responses), with male participants representing 16% (11 responses). The age distribution reveals that the largest segment (56% - 39 responses) fell into the 18–29 age range, indicating a young adult population engaged with the platform and predominantly these reflect young professional practitioners studying and working on early childhood development. This was followed by 30–39-year-olds (20% - 14 responses) and 40–49-year-olds (17% - 12 responses) that again predominantly are practitioners, and a smaller representation of participants over 50 years old (7% - 5 responses). Regarding user roles, the majority (70% - 49 responses) identified as professional practitioners, while the remaining 30% (21 responses) were guardians or family members, reflecting a balanced engagement from both professional and non-professional participants that are involved in early childhood development.

In terms of educational background, the most common qualification among participants was a high school diploma or equivalent (50% - 35 responses), which confirms that this refers to young professionals studying and working on early childhood development. This highlights that a significant participation from users with foundational educational levels. The rest of the participants reported holding higher education degrees, with 21% holding doctoral degrees (15 responses), 19% bachelor's degrees (13 responses) and 10% master's degrees (7 responses). This diversity in terms of educational background suggests the

platform successfully engaged users across a broad spectrum of academic backgrounds, ensuring inclusive feedback for its usability and functionality. This diversity contributes to the robustness of the evaluation, capturing insights from both highly educated professionals and less formally trained users in the early childhood ecosystem.

**Figure 9**

*The UPDEIT study's demographic data*



### 4.3. Results

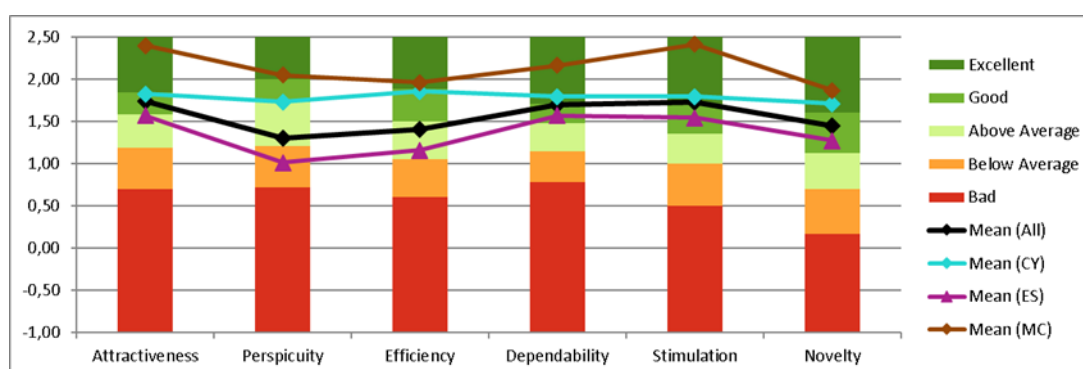
The UEQ instrument assesses six main dimensions of user experience to capture both pragmatic and hedonic qualities. **Attractiveness** reflects the user's overall impression of the product, while **Perspiciuity** measures how easily someone can become familiar with and understand the application. **Efficiency** looks at how quickly and effectively tasks can be completed, **Dependability** focuses on user control and confidence, **Stimulation** gauges the level of excitement or inspiration the product evokes, and **Novelty** evaluates the perceived innovation and creativity of the system.

The UEQ results presented in the graph below (see Figure 10) indicate that the overall user experience is generally positive. The results indicate a positive overall perception of

the platform, with all six dimensions scoring above average. The highest-rated aspects are **Attractiveness (1.74)**, **Stimulation (1.72)**, and **Dependability (1.70)**, suggesting that users find the platform visually appealing, engaging, and reliable. The strong **Stimulation** score implies that users enjoy using the system, while the **Dependability** rating highlights their confidence in its stability and performance. These findings suggest that the application was well-received and fulfilled its intended role in early childhood intervention.

**Figure 10**

*The UEQ evaluation results – Overall and Country-Specific*



However, the results also indicate areas for potential improvement. **Perspicuity (1.30)** and **Efficiency (1.40)** received the lowest ratings, suggesting that some users found the platform slightly challenging to navigate or that the usability of the platform needs to be improved for certain tasks. These findings offer valuable insights for future work. Potential refinements could include simplified navigation, and more intuitive task flows to improve accessibility for all users.

**The Novelty dimension (1.44)**, while scoring positively, was rated lower than Attractiveness and Stimulation. This suggests that while the platform was recognized for its innovation, some users felt it did not significantly differentiate itself from existing solutions during a 3-hour study/workshop. To assess the real impact of this platform, future work should focus on the execution of pilots running over several months, to highlight the key contributions of this work, i.e., the collaborative technical features it provides and the possibility to use multiple platforms and devices to execute tasks. At the same time, additional collaborative features could be introduced, e.g., parents having the ability to upload videos of the child performing new activities and the practitioner being able to provide real-time feedback.

Despite these areas for enhancement, the platform performs well overall, particularly in design appeal, reliability, and engagement. To further elevate the user experience, efforts could be focused on improving efficiency and ease of use by refining navigation and simplifying workflows. Also, introducing more collaborative features could further boost the Novelty rating, making the platform stand out more distinctly from similar applications. While the findings highlight certain usability and novelty challenges, they also serve as a reference point for future projects seeking to enhance digital solutions in this field.

Overall, the responses of participants from North Macedonia (NMs) consistently outperformed both Cyprus and Spain across all six UEQ scales, often by a substantial margin. For **Attractiveness**, NMs' mean of 2.39 sits well within the "Good" benchmark and eclipses Cyprus's 1.82 and Spain's 1.56, indicating that users found the user interfaces markedly more appealing. A similar gap appears for **Perspicuity**, where North Macedonia scored 2.05 ("Above Average") versus Cyprus's 1.73 and Spain's 1.01. This may well indicate that Spanish participants experienced more difficulty understanding and navigating the system.

**Table 1**

*The mean values of the UEQ results – Overall and Country-Specific*

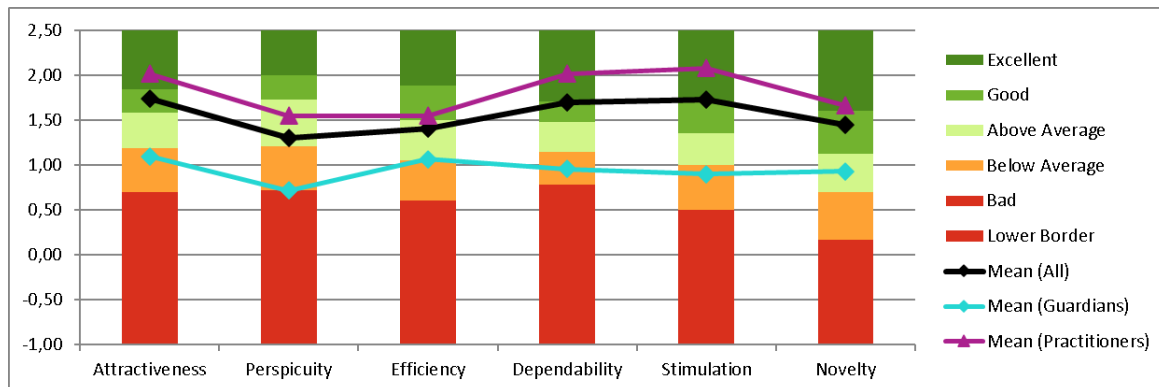
Scale	Mean (ALL)	Comparison to benchmark	Mean (CY)	Mean (ES)	Mean (NM)
Attractiveness	1,74	Good	1,82	1,56	2,39
Perspicuity	1,30	Above Average	1,73	1,01	2,05
Efficiency	1,40	Above Average	1,85	1,15	1,95
Dependability	1,70	Good	1,79	1,56	2,16
Stimulation	1,72	Excellent	1,79	1,54	2,41
Novelty	1,44	Good	1,71	1,27	1,86

On **Efficiency** and **Dependability**, NM again leads (1.95 and 2.16, respectively), while Cyprus maintains solid above-average ratings (1.85 and 1.79), and Spain lags behind (1.15 and 1.56). Notably, **Stimulation**, the only scale rated "Excellent" overall, peaked in NM at 2.41, with Cyprus also high at 1.79 and Spain at 1.54, showing that all users found the platform engaging but with clear national differences in enthusiasm. Finally, **Novelty** scores reflect a similar pattern: NM (1.86) and Cyprus (1.71) both exceed the "Good" threshold, whereas Spain's 1.27 remains closer to the overall mean of 1.44. Overall, while all three countries rate the application positively, NMs users report the strongest user experience and Spanish users the most room for improvement.

Moreover, this study analysed the UEQ scores per user role (Figure 11). Practitioners consistently rated the platform more positively than guardians across all six UEQ dimensions. Practitioner means ranged from 1.55 to 2.08 while guardians' means hovered near or below the above average threshold. For example, perspicuity averaged 1.55 for practitioners and 0.71 for guardians. Practitioners gave attractiveness a mean of 2.01 compared with guardians' 1.10 (overall mean 1.74), dependability scored 2.02 for practitioners compared with 0.95 for guardians (overall 1.70) and novelty was 1.66 for practitioners compared with 0.93 for guardians (overall 1.44). These findings suggest that familiarity with educational technology and domain expertise drive more favorable perceptions of the platform's usability and engagement features.

**Figure 11**

*The UEQ evaluation results – Overall and By User Role*



One limitation of this study lies in the sample size and its distribution across countries, which, since it is uneven, can well introduce bias in the comparison of UEQ scores. The study also relies solely on self-reported data using the UEQ, which captures subjective perceptions and may be influenced by individual expectations or familiarity with digital tools. Furthermore, while MANOVA and ANOVA provide insights into statistical significance, they do not explain the underlying causes of the observed differences, such as interface design preferences, language nuances, or contextual factors in each country's educational or clinical environment. This can be rectified in the future with a qualitative study that is able to document the underlying causes based on the responses of the participants.

#### 4.4. Statistical Analysis

The statistical analysis of the UEQ results provides valuable insights into how users perceive different aspects of the system (Table 2). The mean score represents the average rating that users gave for each dimension, while the standard deviation indicates how much variation there was in those ratings. A lower standard deviation means that most users had similar opinions, whereas a higher standard deviation suggests that user experiences varied more significantly.

The **Confidence value** in the table represents the margin added and subtracted from the mean to establish the **Confidence Interval (CI)**. A smaller confidence value indicates a narrower confidence interval, meaning that responses were more consistent among participants, while a larger confidence value results in a wider confidence interval, suggesting more variability in user feedback.

The confidence interval, shown in the last two columns, provides a range within which the true average score is likely to fall, **with 95% certainty**. This means that if we conducted the study multiple times, 95% of the time, the actual average score would fall within that range. For example, the Attractiveness score **has a mean of 1.738 and a confidence interval of 1.463 to 2.013**, meaning the system is generally perceived as visually appealing, and even in the worst-case scenario, the score remains positive.

**Table 2***The statistical analysis of the UEQ results*

Confidence intervals (p=0.05) per scale						
Scale	Mean	Std. Dev.	N	Confidence	Confidence interval	
Attractiveness	1,738	1,173	70	0,275	1,463	2,013
Perspicuity	1,296	1,334	70	0,313	0,984	1,609
Efficiency	1,400	1,070	70	0,251	1,149	1,651
Dependability	1,696	1,127	70	0,264	1,432	1,960
Stimulation	1,721	1,303	70	0,305	1,416	2,027
Novelty	1,439	1,155	70	0,271	1,169	1,710

Looking at the highest-rated dimensions, **Attractiveness (1.738)**, **Stimulation (1.721)**, and **Dependability (1.696)** all received strong ratings, with their confidence intervals remaining entirely in the positive range. This suggests that users generally find the platform aesthetically pleasing, engaging, and reliable. The relatively small confidence intervals for these dimensions indicate consistent user feedback, meaning that most participants agreed on their positive experience regarding these aspects. **Efficiency (1.400)**, which refers to how easily users can complete tasks, also falls in the positive range, **with a confidence interval of 1.149 to 1.651**, showing that while users find the system effective, there is still some variability in their experiences. The narrow confidence interval for Efficiency suggests that most users agree on its usability, but it might not be as highly rated as the more engaging or visually appealing aspects of the platform.

However, the lowest-rated dimensions, **Perspicuity (1.296)** and **Novelty (1.439)**, reveal areas for improvement. **Perspicuity**, which refers to how easy it is for users to understand and navigate the system, **has a wide confidence interval (0.984 to 1.609)**, meaning that while some users found the system intuitive, others struggled with usability. This variation suggests that certain design and functionality improvements could make the platform more user-friendly. Similarly, **Novelty (1.439)**, which measures how innovative the system feels, **also has a relatively broad confidence interval (1.169 to 1.710)**, indicating that while some users perceive the platform as somewhat innovative, others may fail to understand or evaluate the collaborative features it offers in the short 3 hours period of this study. These aspects can be addressed by conducting an extended study (e.g., 6 months). Moreover, usability aspects can be improved, while at the same time introducing additional collaborative features (e.g., practitioner feedback in real time) could enhance the overall user experience.

The multivariate analysis of variance (MANOVA) using the six **UEQ dimensions** as dependent variables and **Country** as the grouping factor yielded **Wilks' Lambda = 0.7959**, **F = 1.2492**, **p = 0.2576**. It tests whether several outcomes differ jointly across groups. The Wilks' Lambda statistic summarizes how much of the total variance is not explained by the

grouping factor (values near 1 indicate little group effect, values near 0 indicate a strong effect). Because the p-value is well above the conventional 0.05 threshold, we cannot conclude that the overall user-experience profile differs significantly among participants from Spain, Cyprus, and North Macedonia when the six scales are considered together.

The one-way ANOVAs showed that only Perspicuity and Efficiency differ significantly by country. For Perspicuity ( $p = 0.030$ ), North Macedonian users (mean = 2.05) rated clarity and ease of use markedly higher than Spanish users (mean = 1.01), with Cypriots in between (mean = 1.73). Similarly, for Efficiency ( $p = 0.020$ ), North Macedonia's mean of 1.95 significantly exceeded Spain's 1.15 and Cyprus's 1.85. By contrast, Attractiveness ( $p = 0.102$ ), Dependability ( $p = 0.277$ ), Stimulation ( $p = 0.136$ ), and Novelty ( $p = 0.211$ ) did not reach significance despite North Macedonia having the highest means on each scale, indicating that perceptions of the interface's appeal, reliability, motivational quality, and creativity were statistically comparable across the three countries.

The multivariate analysis of variance (MANOVA) using the six UEQ dimensions as dependent variables and User Role (Guardians vs. Practitioners) as the grouping factor yielded Wilks' Lambda = 0.52,  $F = 5.63$ ,  $p = 0.001$ . Because the p-value is below the conventional 0.05 threshold, we conclude that the combined UEQ profiles of guardians and practitioners differ significantly. These results reflect UPDEIT's practitioner-oriented design, as the system was specifically tailored to meet the needs and workflows of practitioners.

In order to confirm the MANOVA results, we have performed a one-way ANOVAs for each UEQ dimension using User Role (Guardians vs. Practitioners) as the grouping factor. This revealed significant role differences in five of the six scales: Attractiveness ( $p = 0.002$ ), Perspicuity ( $p = 0.016$ ), Dependability ( $p < 0.001$ ), Stimulation ( $p < 0.001$ ), and Novelty ( $p = 0.014$ ) all showed statistically significant effects of role. Efficiency did not reach significance ( $p = 0.081$ ), indicating similar perceptions of task-completing speed across guardians and practitioners. The results mirror UPDEIT's practitioner-centered design: developmental specialists found the platform more appealing, clear, dependable, stimulating and novel than guardians, reflecting the system's orientation toward expert workflows and expectations.

Overall, the statistical results confirm that the platform successfully met its primary objectives, providing an effective, engaging, and reliable collaborative tool for ECDI, specifically for developmental specialists.

## 5. Conclusions

The evaluation results of the web application highlight its strengths in stimulation, attractiveness, and dependability, showcasing its usefulness and importance in facilitating ECDI tasks in a collaborative manner. The high ratings in these areas suggest that users find the platform engaging, visually appealing, and reliable, reinforcing its value for both practitioners and guardians. The stimulation score indicates that users feel motivated when using the system, which is a key factor in ensuring long-term adoption and active engagement with the platform. Similarly, the strong dependability rating suggests that users trust the platform's functionality and find it consistent in supporting their tasks, further demonstrating its role as a practical and effective tool for collaborative intervention.

However, the moderate novelty rating suggests that while users recognize the platform's innovative aspects, some perceive it as not significantly different from other existing

solutions. This indicates an area for improvement, particularly in the collaborative features between practitioners and guardians. Given that effective early intervention relies on seamless communication and coordination between these roles, enhancing this feature could bridge gaps in interaction and further improve the overall user experience. Introducing more dynamic and intuitive collaboration tools, such as real-time notifications, interactive feedback mechanisms, or improved user interfaces for data sharing, could strengthen the perceived uniqueness and functionality of the application.

Despite this, the comparison with existing work confirms that the uniqueness of the web application is evident, setting it apart from other platforms in the field. Unlike traditional solutions, the platform not only provides structured developmental tracking, but also fosters a shared responsibility model between practitioners and guardians. The related work section highlights how this system integrates various functionalities in a way that enhances user interaction and engagement, making it a valuable contribution to the field of early childhood intervention technology. With targeted improvements in collaborative features, the platform has the potential to further differentiate itself and set a new benchmark in the domain.

Although the UPDEIT platform will not undergo further development beyond the project's completion, its outcomes carry important implications for both educational policy and practice. The project demonstrates how co-designed, cross-national digital platforms grounded in Universal Design for Learning (UDL) principles, multi-device accessibility, and GDPR-compliant data management, can bridge systemic gaps in early childhood intervention. By enabling real-time practitioner-family collaboration and supporting inclusive, adaptable workflows, UPDEIT offers a replicable model for digital innovation in early childhood education. As education systems increasingly adopt digital technologies, UPDEIT exemplifies how such platforms can serve not only as functional tools, but as catalysts for shared understanding and co-responsibility in developmental care. These lessons are especially valuable for policymakers, institutions, and designers of future ECDI systems seeking to improve equity and access through technology. Finally, the pilot results reflect UPDEIT's practitioner-oriented design, as the system was specifically tailored to meet the needs and workflows of practitioners. The UPDEIT platform remains accessible for demonstration or further research use via: <https://mdl.frederick.ac.cy/UPDEITPlatform>.

#### Author Contributions

Conceptualization: A.A., A. K.-R., C.M., S.P. data curation: A.A., formal analysis: A.K.-R., C.M., funding acquisition: A.A.; investigation: A.A., A. K.-R., C.M., S.P. methodology: A.A., A. K.-R., C.M., S.P.; project administration: A.A.; resources: A.A.; supervision: A.A., A. K.-R., C.M., S.P.; visualization: A.A., A. K.-R., C.M., S.P.; writing-original draft preparation: A.A., A. K.-R., C.M., S.P.; writing-review and editing: A.A., A. K.-R., C.M., S.P.

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#### Ethics approval

Not applicable

#### Consent for publication

All authors have consented to the publication of the results obtained by means of the corresponding consent forms.

#### Conflicts of interest

This study was approved by the Institutional Ethics Committee of the National University of Distance Education.

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### Data Availability Statement

The data set used in this study is available at reasonable request to the corresponding author

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