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Development of "Smart Character Expression" (PRESTER) Application Prototype to Enhance Emotional Intelligence in Deaf Adolescents

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Abstract: Deaf adolescents often face significant barriers in understanding facial expressions and emotions during social interactions due to limited access to auditory information. This research aims to develop a prototype of the "Smart Character Expression" (PRESTER) application as an adaptive learning medium to improve the emotional intelligence of deaf adolescents. Utilizing the Research and Development (R&D) method with the ADDIE model, this study integrates Universal Design for Learning (UDL) principles to ensure content accessibility. The result was an Android-based application featuring a sign language dictionary, various expression forms, and a sign gesture-scanning feature that visually translates emotional meanings. Validation from material and media experts indicates that the prototype is highly feasible. The prototype demonstrates strong potential in bridging the emotional recognition gap for deaf users.

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INTRODUCTION

Adolescence is a transformative phase characterized by rapid physiological, cognitive, and socio-emotional shifts. For deaf or hard-of-hearing (DHH) individuals, this period is often marked by unique challenges that stem not from a lack of cognitive potential, but from significant barriers in accessing the auditory environment. As noted in the foundational theories of special education, deafness is defined by a deficit in the ability to process linguistic information through hearing, which fundamentally alters an individual's interaction with their surroundings. In the Indonesian context, where approximately 7.03% of the population experiences hearing impairments (Infodatin, 2019), the need for specialized support systems is acute. Deaf adolescents at the Junior High School (SMPLB) level, such as those at SLB Negeri Sukoharjo, find themselves at a critical crossroads where the demand for complex social interaction increases, yet their tools for navigating these interactions remain limited due to "language deprivation" (Suharsiwi, 2017). This specific linguistic isolation frequently creates a cumulative delay across executive functioning, pragmatics, and social-cognitive domain development during secondary school ages (Marschark et al., 2017; Convertino et al., 2014). Furthermore, inadequate communication access in early development correlates strongly with heightened academic anxiety and lower self-concept during adolescence (Heriati & Syamsuddin, 2022).

The impact of hearing loss extends far beyond the inability to perceive sound; it affects the very core of communication development. In the theoretical framework of deaf education, communication is the vital bridge for social integration. However, DHH adolescents often face "impairment" in their psychological and anatomical structures, leading to a restricted ability to imitate the verbal nuances that

hearing peers use to understand emotional context. This limitation creates a significant gap in the development of "Theory of Mind" (ToM)—the ability to attribute mental states, such as beliefs, desires, and emotions, to oneself and others. Empirical findings demonstrate that deaf children born to hearing families often score significantly lower on standard false-belief tasks compared to their native-signing peers, indicating that early conversational access, rather than the hearing status itself, shapes early social-cognitive maturation (Jones et al., 2018). Without consistent access to the subtle cues of spoken language, such as pitch, tone, and inflection, deaf adolescents are often left to rely solely on visual stimuli, which can be easily misinterpreted without proper training and tools (Schick et al., 2007; Dyck & Denver, 2003). Consequently, this gap in social-cognitive maturation and the frequent misinterpretation of social cues directly impede the broader development of affective capacities.

This developmental bottleneck is particularly evident in the formation of Emotional Intelligence (EI), defined as the capacity to recognize, understand, and manage one's own emotions while also recognizing and influencing the emotions of others. For deaf adolescents, EI is not merely a psychological asset but a survival skill for social inclusion. Components of emotional intelligence—self-awareness, self-regulation, empathy, and social skills—are often underdeveloped in DHH populations because of limited environmental input (Goleman, 2005). When an adolescent cannot hear the "emotional weight" in a voice, they must depend entirely on facial expressions and body language. According to clinical studies on deaf emotional perception, DHH individuals show distinct cognitive patterns when processing micro-expressions, frequently over-relying on basic structural changes in the lower face while missing holistic emotional cues (Neto et al., 2021; Wiefferink et al., 2013).

Consequently, without a structured pedagogical medium, these visual cues can remain deeply ambiguous, leading to frequent social misunderstandings. Research indicates that the inability to accurately perceive and respond to the emotions of others often leads to frustration, severe social withdrawal, or even reactive aggression. In classroom environments, this affective dissonance frequently compromises the student's peer relationships and heightens internalizing behavioral distress (Hasanah & Nur'aini, 2021). When peer victimization or social rejection occurs, it heavily impacts the psychological well-being of DHH teenagers due to their limited coping mechanisms (Rieffe & Blaauw, 2012). Conversely, structured intervention studies show that when emotional literacy is intentionally trained, DHH adolescents demonstrate marked improvements in self-control and interpersonal resilience (Mouridsen et al., 2019; Sari & Handayani, 2020). Elevating emotional intelligence through visually accessible platforms enables these students to confidently decode complex socio-emotional environments, resolve interpersonal conflicts, and foster psychological autonomy.

The digital era has introduced various assistive technologies, yet many remain heavily "hearingcentric," relying on text density or sound alerts. Existing tools in the Indonesian educational landscape are frequently limited to basic sign language dictionaries (such as SIBI or BISINDO) that focus strictly on semantic vocabulary acquisition rather than the multifaceted emotional nuances of interactive communication (Wati & Kurniawan, 2020; Gunawan & Putro, 2023). This research identifies a critical technological gap: the lack of a mobile-based instructional medium specifically designed to target the emotional development of DHH teenagers.

Mobile technology, particularly the Android platform, offers a unique opportunity for "anytime, anywhere" autonomous learning. Recent studies regarding assistive applications underscore that multi-media designs tailored for mobile touch-screens significantly elevate independent learning performance among students with sensory impairments (Pratama, 2022). By adopting "Universal Design for Learning" (UDL) principles, educational interventions can effectively meet the specific needs of users with varying literacy and language levels (Meyer et al., 2014). The operationalization of UDL via visual technology provides an optimal delivery channel for deaf learners, maximizing spatial-visual cognitive strengths while minimizing dependency on text-heavy descriptions (Al-Azawei et al., 2016; Neild et al., 2022). Assistive technology built upon UDL principles successfully shifts the paradigm of disability from a personal deficit to an environmental accessibility design challenge (Rao et al., 2014; Edy & Setiawan, 2021). Historically, existing UDL-based mobile applications for deaf learners have primarily focused on academic literacy, vocabulary acquisition, or basic sign language translation. While these tools successfully bridge the linguistic gap, they often overlook the socio-emotional dimension of communication, leaving a critical void

in affective learning and emotional recognition training.

To address these multifaceted challenges and bridge the gap left by conventional tools, this study proposes the development of the "Smart Character Expression" (PRESTER) application. The conceptual framework for PRESTER is rooted in the belief that deaf adolescents can achieve high levels of emotional intelligence if provided with the right visual scaffolding. Unlike previous applications that strictly isolate linguistic training from social-emotional skills, PRESTER introduces a novel, integrated approach by serving as a "translator" for the silent world of emotions, turning subtle facial movements and sign gestures into clear, understandable information. The unique contribution of this application lies in its simultaneous feature integration; by combining a sign language dictionary with various forms of emotional expression, PRESTER allows students to study the "grammar of the face" alongside the "grammar of the hands." This dual-focus mechanism fundamentally expands the utility of UDL applications from mere literacy aids into comprehensive platforms for emotional intelligence and micro-expression recognition.

The core innovation of PRESTER lies in its interactive features, particularly the integration of a real-time gesture scanning and expression recognition module. These automated features provide immediate, non-punitive feedback, which is crucial for the adaptive learning styles of DHH individuals. In traditional settings, a deaf student might not realize their facial expression is being misinterpreted as aggressive until a social conflict has occurred. PRESTER enables a safe, digital, risk-free practice where students can refine their expressions independently. This framework directly supports Theory of Mind expansion, training adolescents to critically evaluate how their physical movements and facial configurations are actively perceived by an outside observer (Jones et al., 2018). This research aims to develop and validate a prototype of the PRESTER application using the systematic ADDIE model to provide a vibrant, visual bridge for inclusive communication. To guide the execution and evaluate the outcomes of this study, the following research questions are formulated: (1) How is the "Smart Character Expression" (PRESTER) application prototype architectured and developed based on the Universal Design for Learning (UDL) framework to meet the visual-spatial processing needs of deaf adolescents? (2) To what extent is the PRESTER application prototype valid and feasible according to material and media specialists, and what technical optimizations are required based on their expert judgment? (3) How do deaf adolescents rate the usability of the PRESTER prototype based on Nielsen's framework, and how does the application conceptually support their Theory of Mind (ToM) development within a blended special education setting?

METHOD

This study systematically structures its engineering and testing pipeline into separate procedural domains to ensure replicability and academic rigor.

Research Design

This investigation utilizes the Research and Development (R&D) methodology, which is a research strategy aimed at designing, producing, and scientifically validating specific operational products (Sugiyono, 2016). To ensure a systematic, iterative, and learner-centered development process, this research adopts the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional design framework (Branch, 2009).

Participants and Research Setting

The research was conducted at SLB Negeri Sukoharjo, focusing specifically on the Junior High School for Special Needs (SMPLB) level. The participant ecosystem involved two distinct groups: expert validators and end users. Expert Validators are two material experts (special education university faculty specialists in deaf socio-emotional development) and two media experts (educational technology and software engineering specialists). End-Users is a purposive sample of 10 deaf and hard-of-hearing (DHH) adolescents enrolled at SMPLB Negeri Sukoharjo, selected based on the criteria of utilizing Indonesian Sign Language (BISINDO) as their primary communication mode and possessing basic smartphone literacy.

Research Instruments

Data collection was facilitated through four specialized, validated instruments tailored to match the specific evaluation goals of the ADDIE phases:

a. Expert Judgment Rubrics: A 4-point Likert scale matrix designed for material validators (assessing content accuracy, pedagogical alignment, and linguistic clarity of signs) and media validators (evaluating software stability, UI responsiveness, and multimedia latency).
b. Usability Checklist: A structured field-observation instrument built upon Jakob Nielsen's (1994) usability framework, operationalizing five distinct pillars: Learnability, Efficiency, Memorability, Error Prevention, and User Satisfaction.
c. Digital Response Questionnaires: A simplified, visually enhanced digital questionnaire developed using iconographic cues to capture subjective user satisfaction directly from the deaf adolescent participants.

Data Collection Procedures

The procedural execution followed the sequential mechanics of the ADDIE instructional model:

a. Analysis Phase: A field diagnostic was performed via classroom observations and teacher interviews at SLB Negeri Sukoharjo to examine the impact of "language deprivation" on micro-expression interpretation, establishing the technical requirements for the tool.
b. Design Phase: The researcher formulated a technical blueprint, translating the Universal Design for Learning (UDL) guidelines into storyboards, navigation logic, and system architecture flowcharts.
c. Development Phase: The Android-based PRESTER prototype was programmed, embedding the three core modules (Dictionary, Scanner, and Simulation). This phase culminated in laboratory testing and immediate optimization based on expert validation data (e.g., executing H.264 video compression).
d. Implementation & Evaluation Phase: The optimized prototype was deployed in a limited field trial with the 10 DHH adolescents. Participants engaged in individual learning sessions across four distinct evaluation cycles while being monitored via direct observation and post-trial digital questionnaires.

Data Analysis

The quantitative data derived from the expert judgment rubrics and user satisfaction metrics were analyzed utilizing percentage descriptive analysis. The formulas calculate the cumulative percentage score for each analytical domain, which are subsequently mapped against established educational feasibility thresholds (e.g., determining if a score sits within the "Very Feasible" tier). Qualitative feedback, consisting of written notes from the technical specialists and behavioral responses from the field trials, was processed using thematic grouping to guide the final software adjustments before deployment.

RESULT

The implementation of the Research and Development (R&D) method utilizing the structured ADDIE framework successfully culminated in the creation and validation of the "Smart Character Expression" (PRESTER) application prototype. This section delineates the technical architecture of the developed product, the empirical outcomes of the internal expert judgment, and the usability metrics obtained during the limited field trials with deaf adolescents at the Junior High School (SMPLB) level at SLB Negeri Sukoharjo.

Product Architecture and Visual Design Features

The core physical output of this investigation is a fully functional Android-based mobile application prototype engineered to serve as a high-multimedia assistive tool for emotional literacy. In alignment with the Universal Design for Learning (UDL) framework, the application's interface was designed to heavily prioritize visual-spatial stimuli over traditional text-dense instructions, acknowledging that deaf individuals process information more effectively through structured iconographic and video channels. The application comprises three primary interconnected modules: the Emotional Sign Dictionary, the Interactive Expression Scanner, and the Social Scenario Simulation.

The Emotional Sign Dictionary functions as the conceptual repository of the software, housing 20

distinct emotional states ranging from basic biological affects (e.g., happiness, sadness, anger, fear) to complex social emotions (e.g., embarrassment, empathy, confusion). Each emotional entry is operationalized through a synchronized triad of representation. First, a high-definition video demonstrates the precise Indonesian Sign Language (BISINDO) gesture, performed by a professional interpreter with clear facial visibility. Second, a simplified textual label is provided to reinforce reading literacy concurrently. Third, a dynamically color-coded character icon explicitly mirrors the core psychological state of the emotion—utilizing high-contrast, non-ambiguous visual cues such as bright red for anger or deep blue for sadness.

Figure 1. The Emotional Sign Dictionary interface

The Interactive Expression Scanner represents the primary technological innovation of the PRESTER prototype. By leveraging the smartphone's front-facing camera assembly, the module activates a real-time facial feature tracking script. When a student attempts to replicate a specific emotional expression, the scanner processes the geometric alignment of key facial landmarks—such as eyebrow curvature, lip positioning, and eye widening. The application then delivers immediate, non-punitive visual feedback. If the user's facial configuration matches the emotional parameters, an affirmative green icon appears; if there is a mismatch, the software provides subtle visual prompts indicating which facial area requires adjustment. This real-time processing loop functions as a private, low-anxiety digital mirror for the user.

Figure 2. The Interactive Expression Scanner interface

Lastly, the Social Scenario Simulation module introduces contextual learning. It presents short, loopable, silent video clips depicting common daily social interactions, such as peer conflicts, classroom success, or accidental misunderstandings. Following each clip, the user is presented with a simplified visual multiple-choice interface that asks them to identify the correct emotional state of the character or select the most appropriate emotional response. This module transitions the user from passive emotional recognition to active cognitive evaluation of social environments.

Quantitative Data from Expert Validation

Prior to field deployment, the prototype was subjected to rigorous evaluation by two material experts (special education university faculty) and two media experts (educational technology and software engineering specialists). The evaluation utilized a comprehensive 4-point Likert-scale instrument, and the collected quantitative data were analyzed using percentage descriptive analysis.

Table 1. Validation Indicators and Aspects

Expert Domain	Evaluation Aspect	Assessment Indicators	Scoring Criteria (4-Point Likert)
Material Validation	Content Accuracy	a. Accuracy of psychological definitions for the 20 emotional states. b. Conceptual precision of emotional character representations.	4: Very Appropriate / Highly Accurate (No revision needed) 3: Appropriate / Accurate (Minor revision needed) 2: Inappropriate / Inaccurate (Major revision needed) 1: Very Inappropriate / Entirely Faulty (Total rejection/re-design)
	Pedagogical Alignment	a. Suitability of content for SMPLB developmental milestones. b. Logic sequencing of socio-emotional learning tasks. c. Relevance of social scenario simulations.	
	Linguistic Clarity	a. Accuracy and visibility of professional BISINDO sign interpreters. b. Synchronicity between visual gestures, facial micro-expressions, and text labels.	
Media Validation	Technical Stability	a. Software architecture reliability on Android systems. b. Application response times and gesture-scanning engine processing lag.	4: Excellent / Highly Operational (Fluid performance, no lag) 3: Good / Operational (Stable performance, minor lag) 2: Fair / Poorly Operational (Noticeable glitches/stuttering) 1: Very Poor / Non-Operational (System crashes/fatal errors)
	User Interface (UI) Clarity	a. High-contrast layout design tailored to deaf visual-spatial strengths. b. Unambiguous iconographic and dynamic color-coded cues.	
	Navigational Logic	a. Intuitive dashboard navigation bypassing text-dense instructions. b. Efficiency of information retrieval in the digital indexed dictionary.	
	Multi-media Latency	a. Load times of high-definition video files. b. Frame-rate stability during the real-time facial feature tracking script.	

The Material Validation instrument assessed content accuracy, pedagogical alignment with SMPLB developmental milestones, and the linguistic clarity of the BISINDO videos. The cumulative analysis of the material evaluation yielded an average feasibility score of 92.5%, categorizing the content as "Very Feasible." The experts highly commended the psychological categorization of the emotional characters, noting that the sequence logically matched the socio-emotional needs of deaf teenagers. Qualitative notes from the material experts suggested that the scenario simulation should incorporate

more localized social contexts unique to the Indonesian student experience, such as interacting with traditional market vendors or navigating public transportation, which was subsequently integrated into the final prototype iteration.

The Media Validation instrument focused on software technical stability, user interface (UI) clarity, navigational logic, and multimedia latency. The technical evaluation resulted in an average feasibility score of 89.7%, placing the software architecture firmly within the viable threshold for educational deployment. The engineering specialists highlighted the gesture-scanning interface's high responsiveness and praised its low operational lag on standard Android operating systems. However, a specific technical critique was raised regarding the uncompressed storage size of the high-definition BISINDO video files, which initially caused slight stuttering on entry-level smartphones. In response to this technical feedback, the researcher conducted a systematic video optimization process, applying H.264 compression algorithms to reduce file sizes by 55% while maintaining strict visual clarity of the interpreter's micro-expressions.

Usability and Implementation Metrics

Following the expert-guided revisions, the optimized PRESTER prototype was deployed in a limited field trial involving 10 deaf adolescents at SLB Negeri Sukoharjo. The primary objective was to evaluate real-world usability based on the five pillars of the Nielsen framework: Learnability, Efficiency, Memorability, Error Prevention, and User Satisfaction. The empirical data collected via structured observation checklists and simplified digital response questionnaires yielded an overall cumulative usability index of 88.2%.

The metric for Learnability achieved outstanding results. Without prior training or verbal instructions from the research team, 90% of the participants successfully navigated from the main dashboard to the interactive scanner and completed an emotional recognition cycle in under 180 seconds during their very first session. This rapid onboarding confirms that the iconic, iconographic navigation layout completely bypasses the traditional textual literacy barriers that often render standard educational applications inaccessible to deaf users.

In terms of operational Efficiency, longitudinal observation over four distinct learning sessions revealed that the time required for students to accurately identify a targeted emotional sign decreased by 40% between session one and session four. Rather than searching through cumbersome, static printed sign language manuals, the digital indexed dictionary allowed for instantaneous semantic retrieval.

The User Satisfaction index reached an unprecedented 95%. The qualitative behavioral observations documented intense student engagement, characterized by positive affect, smiling, and repetitive usage of the expression scanner. Several participants explicitly conveyed through sign language that they felt a sense of personal autonomy and excitement because the camera feature allowed them to see their own expressions on screen and verify their clarity. No critical technical crashes or systemic navigation errors were recorded during the testing period, establishing the PRESTER prototype as a technically sound, user-validated, and highly adaptive instructional medium.

The empirical findings from the development and testing of the "Smart Character Expression" (PRESTER) application prototype provide critical insights into the intersection of assistive mobile technology and the socio-emotional development of deaf adolescents. The high validation scores from both academic experts (92.5% for material, 89.7% for media) and real-world users (88.2% for usability) substantiate the core premise of this study: that the communication barriers inherent to deafness can be significantly mitigated when instructional tools are explicitly engineered around visual-spatial cognitive strengths rather than auditory-verbal assumptions.

DISCUSSION

The empirical findings from the development and testing of the "Smart Character Expression" (PRESTER) application prototype provide critical insights into the intersection of assistive mobile technology and the socio-emotional development of deaf adolescents. The high validation scores from both academic experts (92.5% for material, 89.7% for media) and real-world users (88.2% for usability) substantiate the core premise of this study: that the communication barriers inherent to deafness can be

significantly mitigated when instructional tools are explicitly engineered around visual-spatial cognitive strengths rather than auditory-verbal assumptions.

Overcoming Language Deprivation and Cognitive Barriers through UDL

The primary theoretical problem identified in the foundational literature of deaf pedagogy is the phenomenon of "language deprivation." According to recent empirical studies, deaf individuals often demonstrate lower baseline scores in emotional intelligence and facial expression recognition due to restricted early-stage auditory immersion (Neto et al., 2021). In typical development, emotional nuances are continuously internalized through acoustic data—such as hearing subtle changes in vocal inflection, tone, or pitch. Deaf and hard-of-hearing (DHH) adolescents are entirely locked out of this acoustic data, leaving them dependent on visual cues that are frequently missed or misinterpreted without proper training.

The PRESTER prototype directly addresses this cognitive gap by serving as an explicit visual scaffold based on the Universal Design for Learning (UDL) framework. Specifically, the application operationalizes the UDL concept of "Multiple Means of Representation" through its Emotional Sign Dictionary module. By breaking down abstract psychological concepts into a synchronized triad—simplified written text, high-contrast color-coded character icons, and high-definition BISINDO sign language videos—the module completely bypasses auditory requirements. For instance, an abstract emotion like "anger" is represented simultaneously by a bright red icon (visual affect), the textual label, and a professional video showing both the hand gesture and the associated micro-expressions. Studies in inclusive education show that the application of the UDL approach via multi-method multimedia significantly reduces learning barriers and enhances the subjective well-being of children with special needs (Al-Azawei et al., 2016). This multi-channel visual redundancy, engineered inside the Dictionary, enables deaf students to decode emotional concepts independently without experiencing cognitive overload, creating a more equitable and personalized learning pathway (Neild et al., 2022).

Technology as a Catalyst for Theory of Mind Development

Beyond simple vocabulary acquisition, the interactive features of PRESTER facilitate the advancement of Theory of Mind (ToM)—the capacity to realize that other individuals possess distinct mental states, beliefs, and emotional perspectives. This developmental milestone is frequently delayed in deaf teenagers, not because of neurological deficits, but due to restricted interactive experiences with their environment (Jones et al., 2018).

PRESTER accelerates this perspective-taking process by shifting the user from a passive consumer of media to an active, self-reflective participant through the interplay of its Interactive Expression Scanner and Social Scenario Simulation modules. When a deaf adolescent uses the Interactive Expression Scanner, the real-time facial feature tracking script acts as an objective, digital mirror. By requiring students to geometrically align their own eyebrows, lips, and eyes with the target emotion to trigger an affirmative green icon, the technology forces a metacognitive exercise. Students must view their own face from an external perspective, analyzing whether their physical configurations accurately convey their internal state.

This foundational self-awareness is then applied contextually within the Social Scenario Simulation module. By analyzing loopable, silent videos of peer interactions and predicting the characters' feelings through visual choices, students practice reading external mental states. In traditional classroom environments, a deaf student often only realizes their facial expression is ambiguous or aggressive after a social conflict or a misunderstanding has already occurred. PRESTER provides a safe, low-anxiety, and error-tolerant digital laboratory where students can practice the "grammar of facial expression" and situational empathy without the risk of social embarrassment, thereby directly accelerating their perspective-taking skills.

Bridging the Gap: Impairment, Disability, and Handicap

The integration of PRESTER in the curriculum also provides strong support for the technological model of disability interventions, offering a clear blueprint for how technology redefines the continuum of impairment, disability, and handicap for deaf adolescents. Within socio-emotional learning, the impairment is anatomical—the physiological loss of auditory perception. This impairment leads to a

disability (a restriction of ability), which manifests as a reduced capacity to interpret spoken emotional nuances, such as pitch and tone, leading to delayed socio-emotional processing. Traditionally, in a hearing-centric environment, this disability hardens into a social handicap—an environment-imposed disadvantage that isolates deaf adolescents and causes frequent interpersonal misunderstandings.

PRESTER strategically intervenes to disrupt this trajectory by using targeted software design to ensure that the physical impairment does not translate into a social handicap. Prior research indicates that mobile assistive applications, specifically those leveraging the Android platform, are highly effective in increasing social interaction capabilities among deaf individuals (Pratama, 2022). By substituting acoustic cues with localized sign languages (BISINDO) and real-time expression tracking, the technology targets the disability directly.

The high usability score of 88.2% and user satisfaction of 95% demonstrate that when the environment provides customized, deaf-friendly technology, DHH adolescents can achieve emotional competence on par with their hearing peers. The application effectively eliminates the environmental mismatch; while the physical impairment remains, the disability is scaffolded, and the social handicap is dismantled (Wati & Kurniawan, 2020). This technical adaptability breaks down the walls of social isolation, allowing deaf individuals to participate more confidently in an inclusive society.

Implication and Recommendation

From an instructional design standpoint, the exceptional usability ratings demonstrate that mobile technology can drastically boost student motivation in special education settings. Traditional deaf education in Indonesia heavily relies on teacher-centered instruction and static textbooks, which often fail to capture the dynamic, real-time nature of human emotion. The PRESTER prototype proves that mobile applications can grant deaf students a high degree of educational autonomy.

However, a critical pedagogical caveat must be emphasized in this discussion: emotional intelligence is fundamentally a social construct that cannot exist entirely within a digital vacuum. While PRESTER is an exceptionally valid tool for individual practice and cognitive mapping, it cannot replace the necessity of lived human relationships. Therefore, the researcher proposes that PRESTER be utilized strictly within a blended learning framework. In an ideal educational ecosystem, special education teachers at institutions like SLB Negeri Sukoharjo should utilize the application as a baseline diagnostic and instructional tool to introduce emotional concepts. Once the students have mastered the visual vocabulary and practiced their expressions using the digital scanner, the teacher must facilitate structured, peer-to-peer interactive activities in the classroom that translate these digital skills into real-world social competence.

While the current PRESTER prototype demonstrates exceptional technical and pedagogical validity, several specific pathways are recommended to guide its future development and implementation. Future investigations should scale the participant cohort beyond the localized sample through large-scale and multi-center longitudinal field testing, conducting randomized controlled trials (RCTs) across diverse regional special education institutions (SLBs) in Indonesia to validate the generalized efficacy and long-term knowledge retention of the tool over extended academic semesters. Additionally, subsequent iterations should focus on integrating Edge-AI and machine learning models, replacing basic geometric feature-tracking scripts with localized, lightweight deep learning frameworks such as MobileNet or MediaPipe to enable real-time, highly nuanced micro-expression decoding and automatic sign language recognition across varying lighting conditions. The Social Scenario Simulation library should also be expanded to include diverse, culturally specific socio-emotional challenges unique to Indonesian urban and rural environments, such as public transport navigation and peer negotiation in traditional markets. Finally, future software pipelines should focus on the development of a unified cross-platform blended learning framework by engineering a teacher-facing diagnostic dashboard, allowing educators to monitor individual student progress, response latencies, and emotional recognition errors to fully operationalizing PRESTER as a standardized tool within a blended special education curriculum.

CONCLUSION

The development of the "Smart Character Expression" (PRESTER) application prototype represents a significant milestone in assistive technology for deaf and hard-of-hearing (DHH)

adolescents. Based on the systematic execution of the Research and Development (R&D) pipeline utilizing the ADDIE model, this study concludes that the prototype successfully achieves its foundational objectives and explicitly answers the core research questions established at the outset of this investigation. In response to the design and architectural requirements (RQ1), the PRESTER prototype was successfully engineered by operationalizing the Universal Design for Learning (UDL) framework across three interconnected modules—the Emotional Sign Dictionary, the Interactive Expression Scanner, and the Social Scenario Simulation. This structure effectively bypasses traditional text-heavy barriers by providing "Multiple Means of Representation" that align precisely with the visual-spatial cognitive strengths of DHH learners, creating an accessible and intuitive digital ecosystem. Regarding its validity and technical feasibility (RQ2), rigorous evaluation by academic and technical specialists confirmed that the prototype is a highly viable instructional tool, evidenced by a material validation score of 92.5% ("Very Feasible") for pedagogical alignment and a media validation score of 89.7% for architectural stability on the Android platform. Furthermore, expert-guided technical optimization—specifically the implementation of H.264 compression algorithms—successfully reduced video file sizes by 55%, eliminating operational latency on entry-level smartphones. Concerning real-world field usability and theoretical impacts (RQ3), deployment with DHH adolescents at SLB Negeri Sukoharjo generated a cumulative usability index of 88.2% and an unprecedented user satisfaction rate of 95%. The rapid learnability metric confirms that the iconographic interface completely eliminates language-deprivation barriers, while the interactive feedback loop of the facial scanner functions as a low-anxiety digital mirror that promotes emotional metacognition. This active, self-reflective practice directly supports "Theory of Mind" expansion and perspective-taking, while the high engagement levels prove that customized, deaf-friendly technology can systematically dismantle the environmental barriers that turn an anatomical impairment into a social handicap.

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