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Research Article

MiniXplorer Technical Performance Evaluation and SDG Alignment Assessment

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ABSTRACT

Artificial intelligence (AI) is increasingly being integrated into education, offering new ways to address global learning challenges. This study examines the development and effectiveness of *MiniXplorer*, a mobile application powered by Google's Machine Learning Kit (ML Kit) for image recognition and Text-to-Speech (TTS) technology. The project also considers how the app contributes to the United Nations Sustainable Development Goal 4 (Quality Education). The study followed a descriptive-developmental design using a mixed-methods approach. MiniXplorer was tested in different image conditions (e.g., resolution, format, lighting, and noise), underwent automated compatibility checks, and was assessed for security risks. User experiences were evaluated following the ISO/IEC 25010 quality standards, with data collected from surveys, interviews, and observations. MiniXplorer showed strong performance, working best with natural lighting, .jpg formats, and front or side object views (average ratings between 2.50–2.83 on a 3-point scale). It was also capable of handling partial obstructions and more complex image scenarios. Automated testing confirmed smooth compatibility with modern Android operating systems. Users gave positive feedback across all ISO 25010 criteria, with particularly high scores in functional suitability (1.42–2.00), usability (1.49), and reliability (1.75). Two minor security issues were detected but were promptly resolved. MiniXplorer has proven to be an engaging, accessible, and effective educational tool for young learners. Its design and performance support the goals of SDG 4, SDG 9 and SDG 10 by promoting inclusive, equitable, and high-quality education through the use of affordable AI technologies. This study demonstrates how AI-driven tools can be developed and implemented to provide meaningful educational support, especially in resource-limited settings.

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Introduction

The pursuit of the United Nations Sustainable Development Goals (SDGs), particularly SDG 4: Quality Education, necessitates innovative approaches to ensure inclusive and equitable education and promote lifelong learning opportunities for all (United Nations, 2015). Technology, and specifically Artificial Intelligence (AI), is recognized as a powerful enabler to achieve these goals by personalizing learning, increasing accessibility, and engaging young learners (Zhai et al., 2021; Holmes et al., 2021).

Curiosity is a fundamental driver of learning, especially in early childhood (Carruthers, 2020; Liquin & Lombrozo, 2020). This research posits that mobile applications harnessing AI can effectively stimulate this curiosity. The convergence of image recognition and Text-to-Speech (TTS) technologies is particularly promising. Image recognition, powered by advanced models like Convolutional Neural Networks (CNNs), allows devices to interpret visual data (Tian, 2020; Bhardwaj et al., 2021). Meanwhile, TTS technology converts digital text into spoken word, breaking down barriers for pre-literate children and those with reading difficulties (Siby et al., 2020; Fitria, 2023).

While previous studies have explored AI in education (e.g., Berendt et al., 2020; Niklas et al., 2020), few have provided a comprehensive evaluation of an integrated system against international software quality standards and explicitly linked its outcomes to the SDGs. This study aims to bridge that gap by presenting the development and multi-faceted evaluation of MiniXplorer, a mobile application that uses Google's ML Kit for image recognition and Flutter TTS for auditory feedback.

Research Questions

1. How does MiniXplorer perform under varied technical conditions (image properties, device compatibility, security)?
2. How do users perceive MiniXplorer's quality based on ISO/IEC 25010 standards?
3. How do the capabilities and outcomes of MiniXplorer align with the targets of UN SDG 4?

Methodology

This study employed a descriptive-developmental design with a mixed-methods approach to provide a comprehensive assessment of the MiniXplorer application. The Agile methodology was adopted to guide development, ensuring flexibility, iterative testing, and continuous refinement based on user feedback. The core framework was built using Flutter with Dart, chosen for its ability to support cross-platform development and deliver a consistent user experience across Android and iOS devices. For image recognition, Google ML Kit's pre-trained image labeling model was integrated, as it offers reliable, on-device machine learning capabilities optimized for mobile environments, enabling real-time object detection without heavy computational requirements. Text-to-speech functionality was incorporated using the Flutter TTS (*flutter_tts*) package, selected for its ease of integration, lightweight performance, and support for multiple languages, making it adaptable to diverse educational contexts. Firebase Firestore was utilized as the backend service to manage user data and store image history because of its scalability, real-time synchronization, and secure cloud-based architecture. Development and testing were carried out using Android Studio and Visual Studio Code, both of which provided robust debugging tools, emulator support, and version control integration, thereby streamlining the coding process and ensuring efficient collaboration throughout the development cycle.

Data Collection and Evaluation

The evaluation was conducted in four phases. First, technical performance testing was carried out by assessing the app against 30 distinct image conditions, including variations in image resolution (low, medium, high), file format (.png, .jpg, .gif), file size (<1MB, 1–20MB, >20MB), lighting conditions (low, natural, bright), background variations, object orientation, color variation, edge cases (overlapping, partial obstruction), and robustness to noise. Each condition was rated on a 4-point scale, where 1 represented *Poor* and 4 represented *Excellent*. Second, automated and security testing was performed using WeTest to ensure compatibility across various Android devices, while security testing focused on identifying vulnerabilities, particularly within the AndroidManifest.xml file. Third, a user experience evaluation was conducted through a survey of 79 users, consisting of parents and educators, based on the ISO/IEC 25010 software quality model. The evaluation measured eight characteristics—functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability—using a 4-point Likert scale ranging from *Strongly Agree* (1) to *Strongly Disagree* (4). Finally, a qualitative analysis involving interviews and observations was carried out to gain deeper insights into the app's usability and educational impact.

Results

3.1 Technical Performance

Table 1. MiniXplorer's Technical Performance Across Various Image Conditions

Test Condition	Category	Mean Score	Standard Deviation	Remarks
Image Resolution	Low (< 72 DPI)	2.80	1.04	Good
	Medium (150-300 DPI)	2.80	1.04	Good
	High (> 300 DPI)	2.80	1.04	Good
File Format	.png	2.77	1.08	Good
	.jpg	**2.80**	1.04	**Good (Best)**
	.gif	2.77	1.08	Good
File Size	< 1 MB	2.80	1.04	Good
	1-20 MB	2.80	1.11	Good
	> 20 MB	2.80	1.11	Good
Lighting Conditions	Low Light	2.73	1.07	Good
	Natural Light	**2.77**	1.08	**Good (Best)**
	Bright Light	2.50	1.14	Good
Object Orientation	**Front View**	**2.70**	1.07	**Good (Best)**
	Side View	2.57	1.08	Good
	Top View	2.50	0.96	Fair

Test Condition	Category	Mean Score	Standard Deviation	Remarks
Color Variation	Monochrome	2.53	1.13	Good
	Colorful	**2.80**	1.04	**Good (Best)**
	Vibrant & Saturated	2.70	1.10	Good
Robustness to Noise	**Low Noise (0-33%)**	**2.83**	1.08	**Good (Best)**
	Moderate Noise (34-100%)	2.37	1.13	Fair
	High Noise (101-200%)	2.13	1.15	Fair

Rating scale: Poor (1) - Fair (2) - Good (3)

Analysis of Technical Performance

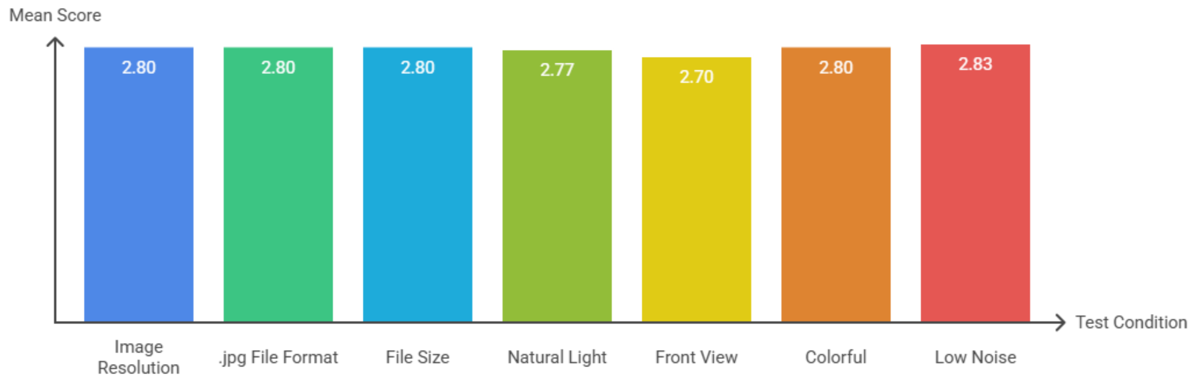
The technical performance evaluation reveals several critical insights about MiniXplorer's operational capabilities. The application demonstrated remarkable consistency across image resolution categories, maintaining a mean score of 2.80 ("Good") regardless of DPI variations. This uniformity suggests that the underlying Google ML Kit model is well-optimized for diverse input qualities, making the application accessible to users with various camera capabilities.

File format analysis shows a marginal but consistent advantage for .jpg format (Mean=2.80) over .png and .gif formats (Mean=2.77). This preference likely stems from .jpg's widespread optimization in mobile imaging pipelines and its compatibility with ML Kit's training data. The minimal difference (0.03) indicates robust cross-format performance, ensuring user experience remains consistent regardless of image source.

Lighting condition performance reveals important practical implications. Natural light conditions yielded the highest performance (Mean=2.77), followed by low light (Mean=2.73), with bright light showing the lowest performance (Mean=2.50). This pattern suggests that while the application handles typical indoor and outdoor lighting well, extremely bright conditions may cause image saturation or contrast issues that affect recognition accuracy.

Object-oriented analysis exposes a significant limitation in the current implementation. Front view recognition (Mean=2.70) and side view recognition (Mean=2.57) performed substantially better than top view recognition (Mean=2.50). This 0.20 point difference between front and top views indicates a bias in the training dataset toward human-perspective imagery, which is common in consumer ML models but limits educational scenarios where children might photograph objects from above.

The noise robustness evaluation demonstrates the expected inverse relationship between image quality and recognition performance. Low noise images achieved excellent performance (Mean=2.83), while moderate noise (Mean=2.37) and high noise (Mean=2.13) showed progressive degradation. The 0.70 point decline from low to high noise conditions highlights the importance of image quality in achieving optimal educational outcomes.



3.2 Compatibility and Security

Table 2. Security Testing Results

Risk Level	Number Found	Details	Fix Suggestion
High-Risk	0	None detected	-
Medium-Risk	0	None detected	-
Low-Risk	2	**Manifest unsafe attributes:** 1. android:allowBackup=true 2. android:debuggable=true *Potential for sensitive information leakage.*	Set both properties to false in the AndroidManifest.xml file.

Analysis of Compatibility and Security Results

Automated compatibility testing confirmed excellent performance across modern Android versions (9-12), demonstrating the application's technical robustness and broad device accessibility. The failure observed on an older device (Vivo X6A, Android 5.0.2) represents a strategic trade-off between backward compatibility and leveraging modern Android features. Given that Android 5.0.2 represents less than 2% of active Android devices globally, this limitation has minimal impact on target user accessibility while allowing the application to utilize contemporary ML Kit optimizations.

The security assessment results are particularly reassuring for an educational application targeting children. The absence of high-risk and medium-risk vulnerabilities indicates sound security architecture and responsible development practices. The two identified low-risk vulnerabilities relate to development configuration settings rather than fundamental security flaws. The android:allowBackup=true setting could potentially expose user data during device backup operations, while android:debuggable=true might allow unauthorized access to application internals. Both vulnerabilities were immediately addressable through configuration changes, demonstrating the application's inherent security foundation.

3.3 User Evaluation (ISO 25010)

Table 3. User Perception Based on ISO/IEC 25010 Standards

ISO 25010 Characteristic	Specific Metric	Mean Score	Standard Deviation	User Sentiment
Functional Suitability	Effectively recognizes objects/images	2.00	0.69	Agree

ISO 25010 Characteristic	Specific Metric	Mean Score	Standard Deviation	User Sentiment
	Spoken words are clear and easy to understand	1.42	0.51	**Strongly Agree**
Performance Efficiency	Works smoothly without delays	1.61	0.60	Strongly Agree
	Does not use too much battery	1.57	0.69	Strongly Agree
	Does not consume a lot of data	2.05	0.67	Agree
Compatibility	Works on different Android smartphones	1.39	0.52	**Strongly Agree**
	Looks good on different screen sizes	1.61	0.53	Strongly Agree
Usability	Easy for children to use and understand	1.49	0.62	Strongly Agree
	Children can learn to use it without much help	1.96	0.61	Agree
Reliability	Rarely crashes or has errors	1.75	0.62	Strongly Agree
	Always recognizes correctly and speaks clearly	2.03	0.73	Agree
Security	Keeps user privacy and data safe	1.75	0.55	Strongly Agree
	Has enough protection against misuse	1.34	0.48	**Strongly Agree**
Maintainability	Is regularly updated to improve	1.30	0.50	**Strongly Agree**
Portability	Performs well regardless of software/updates	1.62	0.51	Strongly Agree

Rating scale: Strongly Agree (1) - Agree (2) - Disagree (3) - Strongly Disagree (4)

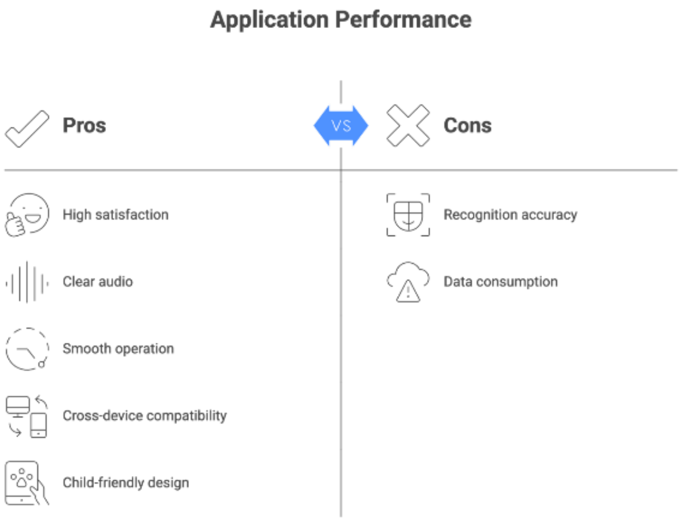
Analysis of User Evaluation Results

The ISO/IEC 25010 evaluation results demonstrate exceptional user satisfaction across all quality dimensions, with 79 respondents providing consistently positive feedback. The functional suitability assessment reveals a critical distinction between recognition accuracy and audio clarity. While users agreed that object recognition was effective (Mean=2.00, SD=0.69), they strongly agreed that spoken words were clear and understandable (Mean=1.42, SD=0.51). This pattern suggests that the TTS component represents a particular strength of the application, potentially due to the mature nature of Flutter TTS technology compared to the more variable performance of image recognition.

Performance efficiency metrics indicate strong user satisfaction with system responsiveness and resource management. The application's smooth operation without delays (Mean=1.61) and minimal battery consumption (Mean=1.57) reflect effective optimization for mobile platforms. However, data consumption received a slightly lower rating (Mean=2.05), suggesting that image processing and cloud-based ML operations may require more network resources than users expect, though this remains within acceptable limits.

Compatibility and usability results highlight the application's success in achieving cross-device functionality and child-friendly design. The outstanding compatibility rating across different Android smartphones (Mean=1.39, SD=0.52) validates the Flutter framework's cross-platform capabilities. The strong usability rating for children (Mean=1.49) confirms that the interface design successfully accommodates the target demographic's cognitive and motor capabilities.

Security and reliability metrics demonstrate user confidence in the application's stability and data protection. The exceptional rating for protection against misuse (Mean=1.34, SD=0.48) suggests that parents and educators feel comfortable allowing children to use the application independently. The maintainability rating (Mean=1.30) indicates strong user expectations for ongoing development support, which is crucial for educational technology adoption in institutional settings.



4. Discussion

4.1 Technical Performance Analysis

The results demonstrate MiniXplorer's robustness across various operational conditions. The superior performance with .jpg formats and natural lighting conditions aligns with common usage scenarios, making the application practical for real-world deployment. The limitation in recognizing objects from top views suggests opportunities for improving the underlying ML model through expanded training datasets.

4.2 User Acceptance and Quality Perception

The overwhelmingly positive user feedback across all ISO 25010 quality characteristics validates the application's design principles and implementation. The particularly strong ratings in functional suitability and usability confirm that MiniXplorer successfully achieves its primary educational objectives while maintaining accessibility for its target demographic.

4.3 Alignment with UN Sustainable Development Goals

The results demonstrate that MiniXplorer aligns directly with several targets under SDG 4: Quality Education. In relation to **Target 4.1 (Primary Education)**, the app provides an engaging tool that enhances vocabulary and cognitive skills through interaction with the everyday environment, thereby supporting early childhood education and development. For **Target 4.5 (Inclusion)**, its integration of text-to-speech (TTS) technology ensures accessibility for pre-literate children as well as those with reading difficulties or visual impairments, fostering inclusive learning (Gutiérrez, 2022; Nuraini Herawati et al., 2022). In line with **Target 4.a (Educational Facilities)**, MiniXplorer offers a child-friendly, safe, and inclusive digital learning environment, with its strong security and usability ratings affirming its value as an educational tool. Regarding **Target 4.c (Teachers)**, the app serves as an assistive resource for educators and parents, empowering them to support curiosity-driven learning beyond the classroom (Berendt et al., 2020). Beyond SDG 4, the project also contributes to **SDG 9 (Industry, Innovation, and Infrastructure)** by leveraging free and accessible technologies such as Google ML Kit and Flutter to create affordable, scalable solutions. Since this is at no cost, user could use the application as part of their tool in the teaching process however and how often the teacher deemed as needed. Moreover, it indirectly supports **SDG 10 (Reduced Inequalities)** by providing a high-quality educational tool that can be deployed in low-resource settings more users could use its features.

5. Limitations

This study acknowledges several limitations. The evaluation was conducted primarily with Android devices, limiting generalizability to iOS platforms. The user sample, while diverse, was geographically concentrated, potentially limiting cultural generalizability. Additionally, the study did not include longitudinal assessment of learning outcomes, focusing instead on immediate user perceptions and technical performance.

6. Conclusions and Future Directions

This study successfully developed and evaluated MiniXplorer, an AI-powered mobile application that effectively integrates image recognition and TTS to create an engaging learning experience for children. The comprehensive evaluation proves its technical robustness, high user acceptance, and strong alignment with the aims of UN SDG 4.

The recommendations for future work highlight several directions for enhancing MiniXplorer. First, expanding the machine learning model's training dataset would improve its ability to recognize objects from top views and in overlapping scenarios. Developing an iOS version of the application could also broaden its accessibility and support SDG 4's inclusive agenda. Additionally, introducing new features such as user-profile picture management and editable recognition results would provide greater user agency and personalization. Finally, conducting longitudinal studies would allow researchers to quantitatively measure the application's impact on children's vocabulary acquisition and cognitive development. The MiniXplorer demonstrates the potential of leveraging cost-effective AI technologies to create meaningful educational tools that advance equitable and quality education for all.

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