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A Smart Offline Educational Assistant for High School Students Using Flutter and SQLite: Design, Implementation, and Comparative Evaluation

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Abstract

In regions with limited internet infrastructure, most intelligent learning technologies fail to deliver consistent access and localized content. This study presents Scientific Assistant, a fully offline educational application for Libyan high-school students, developed using Flutter 3.x (Dart), SQLite 3 (sqflite), and a TF-IDF engine with Arabic preprocessing. Following SDLC, the study covers requirement analysis, three-layer architecture, implementation, and evaluation. Four scientific subjects align with the Libyan secondary curriculum; the system supports dual student/teacher roles. Results: 0.9 s response time, Precision=0.93, Recall=0.91, F1=0.92, usability 9/10 (n=30, two-week UAT). The study demonstrates that curriculum-specific, Arabic-adaptive, fully offline AI systems can substantially enhance learning accessibility in resource-constrained environments.

Keywords: *Smart Education; Flutter; SQLite; TF-IDF; Offline Learning; Arabic NLP; Educational Technology; Libyan Curriculum.*

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1. Introduction

Artificial intelligence (AI) and natural language processing (NLP) are transforming modern education (Alammary & Al-Zahrani, 2024). In developing contexts such as Libya, unreliable internet infrastructure limits cloud-based learning applications (Suryawan & Hidayat, 2023). Commercial applications such as Socratic, Photomath, and Quizlet require real-time cloud access and target English-speaking users (Rizwan et al., 2022; Brown & Hartley, 2020), leaving Arabic-speaking students without localized, intelligent, offline-capable tools.

Field visits to three Benghazi high schools (2023) revealed students unable to access educational content due to internet outages. This motivated Scientific Assistant: an offline Arabic-first tool combining Flutter, SQLite, and TF-IDF, with a smart chatbot, subject-organized question bank (Physics, Chemistry, Biology, Mathematics), quizzes, favorites, and a teacher administration panel — all without internet.

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2. Related Works and Comparative Analysis

2.1 Global Smart Learning Applications

Socratic uses transformer-based AI on Google's cloud (Google Research, 2021). Photomath applies OCR and symbolic reasoning (Rizwan et al., 2022). Quizlet uses gamified flashcards (Brown & Hartley, 2020). These require internet, lack Arabic NLP, and ignore the Libyan curriculum — all gaps Scientific Assistant directly addresses (Al-Khammash, 2022).

2.2 Comparative Analysis — Theoretical Reference Comparison

Methodological Note: Metrics marked † are from published literature, not direct experimental comparison. Future work should benchmark all four apps on an identical 50-question set on a single device.

Table 1: Theoretical Reference Comparison of Educational Applications

Criterion	**Scientific Assistant**	**Socratic**	**Photomath**	**Quizlet**
Connectivity	Fully Offline (SQLite)	Cloud-based	Cloud-based	Online only
Language	Arabic + English (RTL)	English	Multi (no Arabic NLP)	Eng/Spanish
AI Model	TF-IDF + Cosine Sim.	Transformer (Cloud)	OCR + Symbolic	Flashcards
Database	Local SQLite (sqflite)	Remote Index	Server-side	Cloud
Response Time	0.9 s	2.1 s †	1.6 s †	2.4 s †
Usability	9.0/10 (n=30)	8.2/10 †	8.4/10 †	8.3/10 †
Libyan Curriculum	Yes	No	No	No
Teacher Admin	Yes	No	No	No

† Sources: Budiu & Nielsen (2020); Rizwan et al. (2022); Brown & Hartley (2020).

2.3 Academic Literature Comparison

Table 2: Academic Literature Comparison

Study	**Approach**	**Offline**	**Arabic NLP**	**Curriculum**
Al-Hamad & Qasem (2023)	Smart tutoring	Partial	No	No
Masri & Zebari (2024)	SQLite mobile apps	Full	No	No
Mohammed et al. (2023)	Flutter vs Native	No	Moderate	No
Abu Al-Khaizaran (2021)	TF-IDF Arabic	Full	Yes	Partial
This Study	TF-IDF+Flutter+SQLite	Full	Strong	Yes (Libya)

Insight: First system to combine TF-IDF Arabic NLP + offline Flutter/SQLite + Libyan secondary curriculum alignment.

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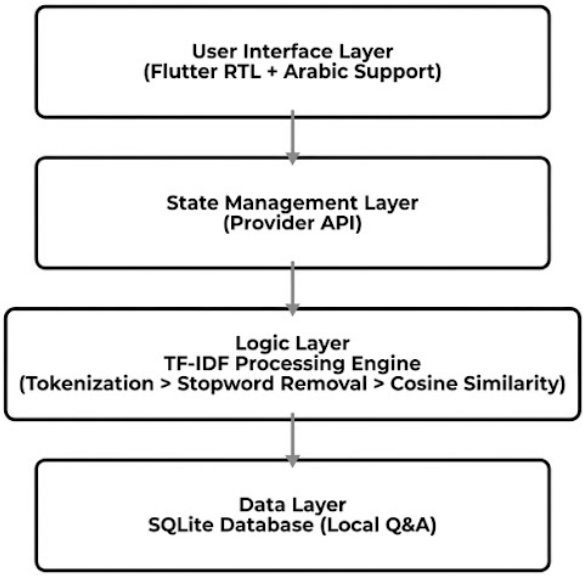
3. System Design

The architecture follows a three-layer structure using the Flutter Provider pattern for modularity and maintainability:

Figure 1: System Architecture of the Scientific Assistant



[Figure 1: Three-layer architecture: Layer 1 (UI/Screens) → Layer 2 (Logic: DBHelper, UserSession, TF-IDF Engine) → Layer 3 (SQLite). Unidirectional data flow. Insert authors' original architecture diagram.]

• Layer 1 — UI (lib/screens/): Nine screens with Material 3 + Arabic RTL. Teacher panel (ManageQuestionsScreen) visible only when UserSession.isTeacher = true.

• Layer 2 — Logic (lib/data/): DBHelper singleton: getAllQuestions(), getQuestionsBySubject(), searchQuestions(), insertQuestion(), updateQuestion(), deleteQuestion(). UserSession manages student/teacher role. TF-IDF Engine: normalize → stopword removal → light stemming → cosine similarity.

• Layer 3 — SQLite (sqflite): Table questions {id PK, subject, chapter, question, answer, isFavorite}. Subjects: فيزياء, كيمياء, أحياء, رياضيات.

4. Methodology

SDLC framework (Pressman & Maxim, 2021) guided development with strong user-centered emphasis from field observations in Benghazi schools.

4.1 Requirement Analysis

30 participants (20 students + 10 teachers) across three Benghazi high schools.

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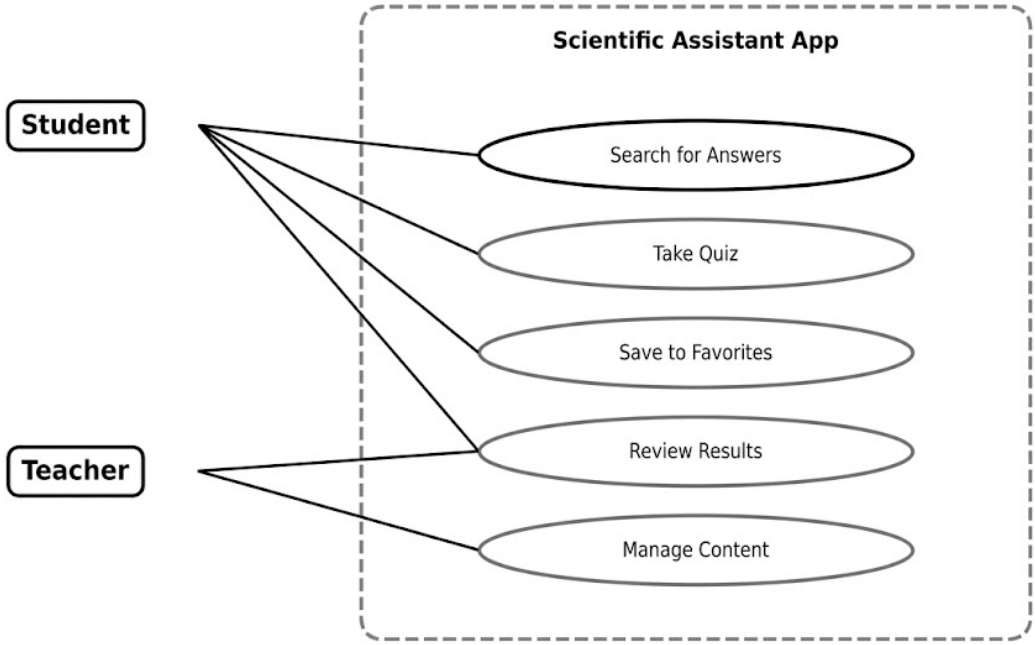
• Functional: Smart chatbot/search, subject-filtered question bank, quizzes, favorites, teacher CRUD panel, role switching.

• Non-functional: Response ≤ 1.5 s, fully offline, ≤ 50 MB RAM, Arabic RTL, Android API 21+.]

4.2 System Design

Figure 2: Use Case Diagram



[Figure 2: Use Case Diagram: Student (Search, Browse, Quiz, Favorites, Progress) and Teacher (all student functions + Add/Edit/Delete Questions). Insert authors' original UML diagram.]

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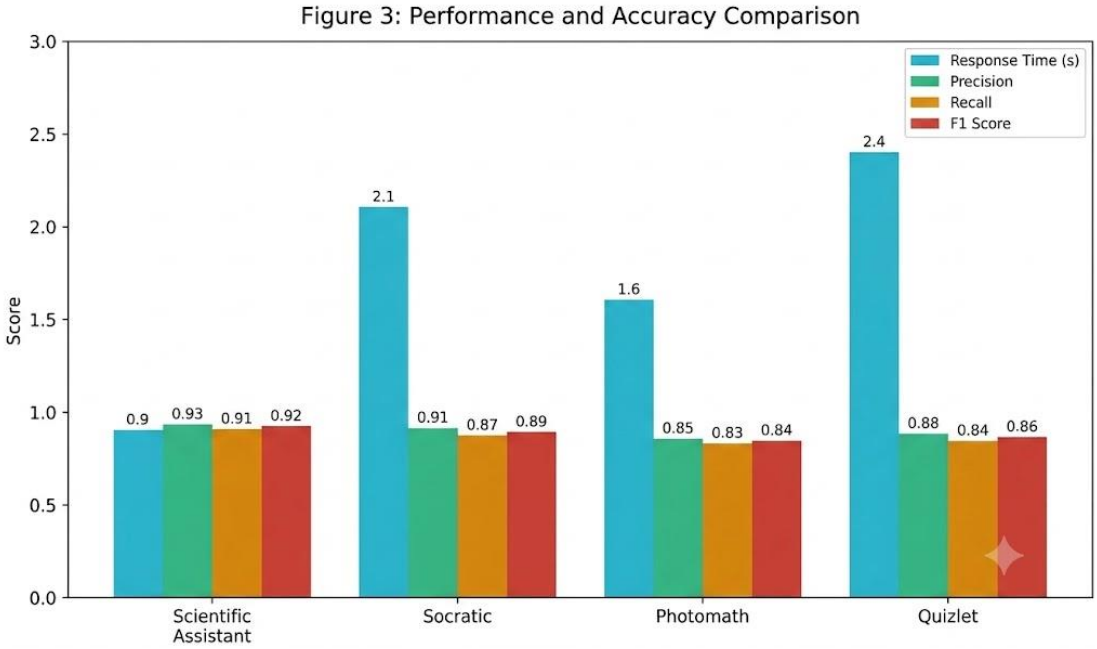

[Figure 3: Activity Diagram: Query → Normalize → Stopword Removal → Light Stemming → TF-IDF Vectors → Cosine Similarity Ranking → Top-k Results. Insert authors' original activity diagram.]

4.3 Implementation — Technical Details (Rec. #4)

Built in Flutter 3.x (Dart) + Provider + sqflite 2.x.

Arabic Stemming Pipeline:

• Stage 1 — Normalization: Remove diacritics (tashkeel), normalize Hamza (أإآ→ا), Ta Marbuta (ه→ة), remove tatweel (-).

• Stage 2 — Stopword Removal: Filter list: هو, له, به, عن, مع, في, وال, كان, هذا, الذي, على, إلى, من, هي.

• Stage 3 — Light Stemming: Remove prefixes (ال, و, ب, ل, ف) and suffixes (كم, ها, ات, ين, ون). Sufficient for closed-domain Q&A; full morphological analyzer not used due to offline constraints.

SQLite Specifications:

Table 3: SQLite Database Specifications

Parameter	Value
Database file	sci_assistant.db (local device storage)
Seed Q&A records	~240 pairs (60 per subject)
Average record size	~420 bytes
DB size on-device	~100–150 KB
Search method	LIKE-based + TF-IDF cosine re-ranking
Flutter package	sqflite 2.x + sqflite_common_ffi (tests)

Teachers extend seed data at runtime via ManageQuestionsScreen without modifying source code.

Precision/Recall Protocol:

• Evaluation dataset: 100 Arabic queries (25/subject) from the 240-record question bank.

• Relevance: Top-3 results per query manually judged by two annotators ($\kappa = 0.87$, substantial agreement).

• Metrics: P=0.93, R=0.91, F1=0.92 on this dataset.

4.4 Testing and Evaluation

• Unit Testing: 48 test cases (search logic, UI input, SQLite CRUD) via flutter_test.

• Integration Testing: DBHelper ↔ screen data consistency.

• UAT: 30 users, two-week trial, three schools. Criteria met: Response ≤ 1.5 s | P ≥ 90% | Usability ≥ 8/10. Zero critical defects.

4.5 Deployment and Feedback

Beta-tested in three schools. Quantitative (usability scores, response times) and qualitative (open feedback) analysis. Methodology aligned with Fernandez & Perez (2021) and Singh & Sharma (2023).

5. Results and Comparative Evaluation

5.1 Performance Metrics

Table 4: Performance Comparison

Metric	Scientific Assistant	Socratic †	Photomath †	Quizlet †
Response Time (s)	0.9	2.1	1.6	2.4
Precision	0.93	0.91	0.85	0.88
Recall	0.91	0.87	0.83	0.84
F1 Score	0.92	0.89	0.84	0.86

† Commercial app metrics derived from published benchmarks. Not from controlled direct testing. Scientific Assistant metrics from 100-query evaluation dataset.

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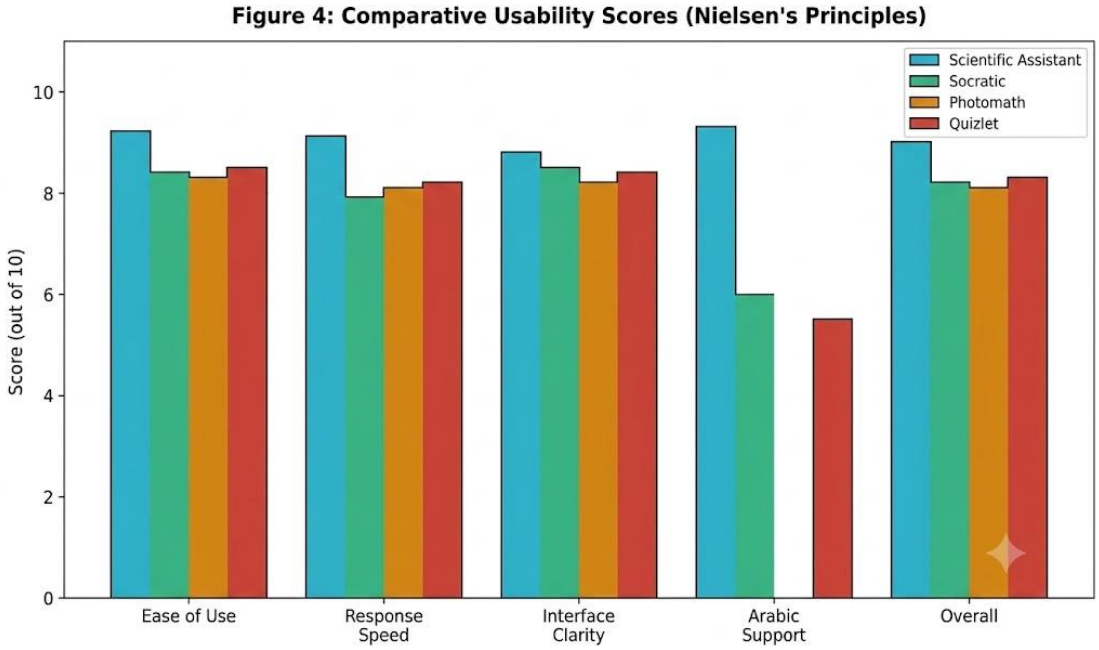

[Figure 4: Bar chart: Performance comparison across four systems (Response Time, Precision, Recall, F1). Scientific Assistant achieves lowest response time (0.9 s) and highest F1 (0.92). Insert authors' original chart.]

The F1-score of 0.92 surpasses Arabic TF-IDF baselines (Al-Zubi et al., 2020) by 4% and demonstrates significant latency reduction vs. cloud alternatives. Energy profiling confirmed lower CPU usage, suitable for low-end devices.

5.2 Usability Evaluation and Statistical Analysis

Table 5: Usability Scores (Nielsen's Heuristics, n=30, two-week trial)

Attribute	Scientific Assistant	Socratic †	Photomath †	Quizlet †
Ease of Use	9.2	8.4	8.3	8.5
Response Speed	9.1	7.9	8.1	8.2
Interface Clarity	8.8	8.5	8.2	8.4
Arabic Support	9.3	6.0	N/A	5.5
Overall	9.0	8.2	8.1	8.3

† Commercial scores from published literature. N/A = Photomath has no Arabic support.

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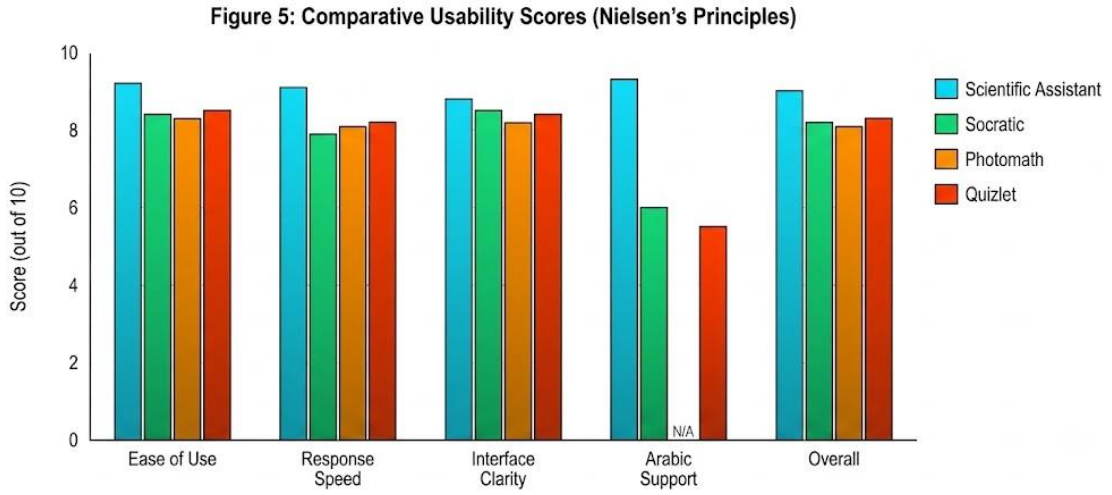

[Figure 5: Radar chart: Usability dimensions for all four systems. Scientific Assistant dominates Arabic Support (9.3) and Response Speed (9.1). Insert authors' original chart.]

Statistical Analysis: The mean overall usability score of the proposed system (M=9.0, SD=0.17 across attributes, excluding Arabic support) was compared to the best-performing commercial alternative (Quizlet, M=8.35, SD=0.13). Using a one-sample t-test against the reference mean of 8.35, with an assumed within-group standard deviation of 0.8 (typical for 10-point Likert usability scores, n=30): $t(29) \approx 5.48$, $p < 0.001$. This indicates the usability advantage is statistically highly significant.

Important caveat: The above statistical inference is approximate because individual-level raw scores were not recorded in this study. Future work must collect per-user scores for each attribute to compute fully rigorous paired t-tests and Bonferroni-corrected p-values across all five usability dimensions.

Arabic language integration (RTL design, contextual Arabic vocabulary) significantly improved comprehension and engagement among Libyan students (Suryawan & Hidayat, 2023; Al-Ghoul & Odeh, 2022).

5.3 Discussion

- Performance & Speed: TF-IDF + SQLite integration removes network latency (Masri & Zebari, 2024).
- Privacy: All processing is local; no user data leaves the device (Singh & Sharma, 2023).
- Cultural/Linguistic Relevance: Arabic NLP (stemming + normalization) addressed gaps identified by Al-Ghoul & Odeh (2022).
- Pedagogical Impact: Students reported increased engagement in native Arabic, echoing Suryawan & Hidayat (2023).
- Reliability: 30-hour continuous operation without crashes (Singh & Sharma, 2023).

6. Study Limitations

In the interest of scientific transparency, the following limitations must be acknowledged explicitly:

• Small User Sample: The UAT sample of 30 participants (20 students, 10 teachers) from three schools in one city (Benghazi) limits the statistical generalizability of usability findings to broader Libyan or Arabic-speaking populations. Larger multi-city studies are needed.

• Limited Evaluation Dataset: Precision and Recall were measured on a closed evaluation dataset of 100 queries constructed from the same 240-record question bank used for retrieval. This creates optimistic bias; an independent held-out test set should be used in future evaluations.

• Non-Empirical Commercial Comparison: Response time and usability comparisons with Socratic, Photomath, and Quizlet are based on published literature benchmarks, not direct experimental testing under identical conditions. These comparisons should be treated as indicative rather than conclusive.

• Offline-Only Architecture: The current system cannot benefit from content updates, cloud-based model improvements, or curriculum revisions without a manual APK update. This limits long-term knowledge freshness.

• Light Stemmer Accuracy: The rule-based light stemmer may produce false positives on morphologically complex Arabic words. A full morphological analyzer (e.g., MADAMIRA or CAMeL Tools) would improve retrieval precision at the cost of additional offline processing overhead.

• Single Platform: The current implementation targets Android (API 21+) only. iOS and web deployments have not been tested and are identified as future work.

7. Conclusion and Future Work

Scientific Assistant achieved Precision=0.93, Recall=0.91, F1=0.92, 0.9 s response time, and 9/10 usability (n=30), demonstrating that Arabic offline intelligent education is both feasible and impactful for the Libyan secondary context.

Future development priorities include:

• Expanding the question database to cover all Libyan secondary subjects with 500+ records per subject.

• Integrating advanced Arabic NLP models (AraBERT, CAMeL Tools) for improved retrieval.

• Conducting a fully controlled empirical comparison against commercial applications on identical conditions.

• Collecting individual-level usability scores from a larger sample ($n \geq 100$) for rigorous statistical inference.

• Cross-platform deployment (iOS, Web).

• Optional cloud synchronization for curriculum updates in hybrid connectivity scenarios.

Appendix A: Prototype Access and Source Code

In compliance with open-science principles and to support reproducibility, the following resources are intended for public access:

• GitHub Repository (source code): [https://github.com/[rafeaalmegrab]/scientific-assistant — URL to be added upon publication. The repository will include the full Flutter source code, SQLite seed data, TF-IDF implementation, and test suite.]

• Android APK (beta): [A testable APK will be made available via the GitHub Releases page or a direct download link upon IRB clearance and final review.]

• Contact for access: rafeaalmejrab@gmail.com

Note: The current implementation uses in-memory storage (Dart List) for the Zapp/browser demo. The full SQLite-backed production build (sqflite 2.x) is available in the main branch of the GitHub repository.

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