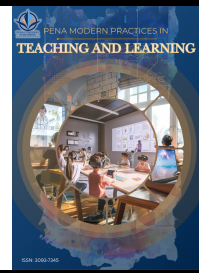




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Developing an Interactive Augmented Reality Application for Exploring Malaysian Flowers: Learning in Bloom

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ABSTRACT

Traditional botanical education in Malaysia relies primarily on passive instructional resources, contributing to plant blindness, a generational knowledge gap, and difficulty distinguishing native from non-native floral species. Objective: This study evaluated the Learning in Bloom mobile augmented reality (AR) application to assess its effectiveness in improving floral care knowledge, identifying agricultural information-access challenges, and promoting environmental awareness among users. Method: Guided by the ADDIE instructional design framework, the application paired physical QR-code learning cards with interactive three-dimensional models of five Malaysian flower species built on the Assembler platform. Usability and satisfaction were evaluated through a post-interaction survey of fifty-one respondents. Key Results: 68.6% of participants initially lacked confidence in their local botanical knowledge; following interaction, 74.5% preferred visual and interactive botanical content, 80.4% expressed high interest in regional flora, and 92.1% reported that studying flowers improved their respect for the natural world. Conclusion: The Learning in Bloom application offers an engaging digital environment that increases interest in and appreciation of local biodiversity, although its content currently covers only basic botanical facts due to development constraints.

1. Introduction

1.1 Background and Context

Augmented Reality (AR) has emerged as a significant educational technology within scientific study, allowing students to visualize complex concepts through interactive three-dimensional models and animations [1]. By imposing digital content onto the physical world, AR creates immersive, dynamic, and engaging learning experiences that bridge the gap between abstract academic theories and concrete real-world observations. Within botanical and environmental education, this technology offers an innovative platform to explore floral structures and ecological significance, moving beyond the limitations of static textbook imagery to bring botanical subjects to life in three dimensions.

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1.2 Problem Statement

Despite global trends demonstrating that digital visualisation tools significantly increase student information retention, traditional Malaysian classrooms continue to rely primarily on passive instructional resources. These conventional methods, consisting of textbooks, posters, and teacher-centred "chalk-and-talk" lectures, lack the experiential depth and interactive involvement necessary to engage students effectively. Consequently, students struggle to identify fundamental botanical features, such as petal structures and reproductive organs, and find it difficult to distinguish native Malaysian flower species from non-native ones without practical, immersive visual aids.

This gap is compounded by curricular and cultural omissions. Traditional biological knowledge and botanical practices, such as using local plants for cooking and medicine, are rarely integrated into regular Malaysian school curricula, and this absence has produced a distinct generational knowledge gap: contemporary Malaysians are now more adept at identifying foreign ornamental flowers seen on social media than the native species that define the ecological and cultural identity of their own nation. The slow adoption of interactive three-dimensional modelling in Malaysian classrooms further represents a missed opportunity in environmental education, conflicting with United Nations Sustainable Development Goal 4 (SDG 4), which advocates for creative, high-quality educational experiences. Without such immersive tools, students struggle to conceptualise abstract biological processes like pollination and seed movement, which limits their development of an active, meaningful connection to local environmental conservation.

1.3 Research Objectives

To address these educational and ecological gaps, the Learning in Bloom mobile application was developed to merge technology with environmental education, creating an engaging foundation for exploring Malaysian biodiversity. The study evaluated the application against three objectives:

- i. To evaluate the effectiveness of the flower app in improving knowledge about flower species, care techniques, and cultivation practices for florists and farmers.
- ii. To identify the challenges florists and farmers face in accessing reliable information on flowers, seasonal care, and sustainable farming practices, and how the app can help overcome these challenges.
- iii. To determine the impact of the flower app on promoting environmental awareness, plant conservation, and engagement with local flora among florists, farmers, and general users.

2. Literature Review

2.1 Mobile Augmented Reality in STEM and Biological Sciences Education

The integration of mobile Augmented Reality (mAR) in Science, Technology, Engineering and Mathematics (STEM) education represents a shift from teacher-centred delivery to interactive, student-centred visualisation. Augmented reality improves STEM learning outcomes by reducing the cognitive load required to understand complex spatial configurations and physical phenomena [2]. mAR applications have been shown to raise academic performance, enhance student engagement, and increase overall interest in scientific study [3], allowing students to manipulate digital representations of real-world elements and making learning more experiential and memorable. Within secondary biology curricula specifically, interactive environments foster learner autonomy, collaborative inquiry, and academic satisfaction [4], and applying mAR within flipped-classroom models has shown benefits for students' problem-solving capacity and cognitive performance [5].

This is consistent with a systematic review of mobile augmented reality frameworks in STEM, which emphasised that effective educational applications must balance real-time digital interaction with precise three-dimensional registration to avoid user disorientation [6]. Relatedly, while AR promotes active learning in science classrooms, there remains a persistent lack of localised, curriculum-specific platforms, which limits the long-term utility of these technologies in national education systems [7]. The Learning in Bloom application addresses this gap directly: while many existing STEM frameworks use general or foreign biological models, this study focuses explicitly on native Malaysian floral species, aligning interactive digital visualisation with local ecological education. By presenting five culturally and ecologically significant flowers, namely the hibiscus, Rafflesia, orchid, rose, and sunflower, the application contextualises abstract biological topics within the local environment, supporting the educational-quality goals of SDG 4.

2.2 Interactive Digitisation of Botanical Morphology and Species Identification

Teaching botanical morphology through textbooks and static diagrams presents significant challenges, as students often struggle to conceptualise the intricate internal and external structures of plants. Prior work has addressed this through purpose-built AR tools: the feasibility of using mAR to introduce the morphological features of the Wijaya Kusuma flower has been demonstrated [8,9], and detailed study of floral structures in species such as *Averrhoa dolichocarpa* highlights the value of accurate, three-dimensional spatial representations for taxonomic identification [10]. More recently, the PetalsPalette application illustrated how augmented reality can bridge digital technology and natural environments to enhance botanical learning and floral identification [11].

Despite the success of these specialised tools, many students continue to experience "plant blindness", a cognitive bias in which individuals overlook the plant species in their immediate surroundings. Mobile plant-identification applications combined with out-of-school, field-based learning have been found to increase engagement and taxonomic recall, but often fail to explain the deeper morphological function or ecological importance of the identified plants [12]. A comparative usability analysis of commercial plant-recognition applications similarly found that computer-vision-based tools, while efficient for name retrieval, function largely as informational "black boxes" that do not actively teach structural biology or local environmental context [13]. The Learning in Bloom application extends this body of work by moving beyond automated identification to active biological instruction: rather than passive text labels or automated photo scans, it uses interactive three-dimensional models, developed on the Assembler platform, that users trigger by scanning physical QR codes to reveal labelled anatomical overlays (petals, sepals, stamens, and pistils).

2.3 Technological Integration in Agricultural and Floriculture Knowledge Systems

While educational mAR research typically targets primary and secondary biology students, there is an emerging need to integrate these tools into vocational and agricultural contexts. The Learning in Bloom application addresses this by extending its target user base to local florists and farmers, who frequently face difficulty accessing reliable, localised information on plant care, seasonal cultivation, and sustainable farming. Researchers have emphasised the importance of preserving local plant diversity and bridging the generational knowledge gap regarding native flora [14,15], noting that traditional botanical practices and conservation strategies are often maintained by indigenous and rural communities with limited access to modern digital resources [16].

Within modern agriculture, mobile decision-support systems that combine augmented reality with three-dimensional computer vision are increasingly used to optimise cultivation workflows;

industry projects such as iVine and iAgro have demonstrated smartphone-based AR and 3D scanning for monitoring crop health and planning precision-agriculture inputs [17]. Industry reporting nonetheless notes that such platforms are often complex, costly, and dependent on continuous high-bandwidth connectivity, which makes them inaccessible to small-scale farmers and independent florists [18]. The Learning in Bloom application offers a lower-cost alternative: by pairing fundamental scientific knowledge with localised botanical detail (species names, care techniques, cultivation guidelines) delivered through simple, offline-capable QR cards and three-dimensional visualisations, it gives small-scale agricultural workers a more accessible route to reliable botanical care information.

2.4 Systemic Instructional Design and the ADDIE Framework

The educational efficacy of any technological application depends heavily on the systematic structure of its design and development process. The five-phase ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) is widely used as a standard for structured learning-application design; it has, for example, underpinned the development and validation of a plant-education learning module [19], and integrating mAR applications into regional school curricula more broadly requires a comparable framework to align digital visual elements with national educational goals [20]. The development of Learning in Bloom follows this structure, and its five phases are detailed in Section 3.3.

3. Methodology

3.1 Research Design

A quantitative research design was used to evaluate the effectiveness, usability, and educational impact of the Learning in Bloom mobile AR application. This approach was selected to collect structured, measurable data on user satisfaction, visual design quality, interface usability, and learning progress. Data were gathered through a standardised questionnaire administered after users interacted with the application; a paired pre-test/post-test protocol was also designed to measure participants' botanical knowledge before and after the interaction. A total of fifty-one respondents took part in the evaluation. (The exact sampling strategy and full demographic breakdown of the fifty-one respondents, by student, florist, farmer, and general-user category, are not stated in the source materials reviewed for this manuscript and should be added by the author before submission — see the accompanying action-item list.)

3.2 Materials and Hardware/Software Specifications

The interactive three-dimensional botanical models and augmented reality features were built using the Assembler development platform, which was used to design the 3D models, coordinate spatial layouts, and generate the physical-to-digital tracking links. The application used the built-in camera sensors of standard mobile devices to perform image-based scanning of the physical tracking markers.

3.3 Product Design and Development (ADDIE Model)

The design, production, and deployment of the Learning in Bloom application followed the five-phase ADDIE instructional design model, a widely used paradigm for developing computer-assisted and augmented reality educational materials [21]:

Analysis phase: the project objectives, target user profile, and learning needs were identified. The target audience was defined as students, young learners, and nature enthusiasts requiring accessible botanical information, and the technical feasibility of displaying interactive 3D models on standard mobile devices was assessed.

Design phase: the application structure, user flow, interface design, and interaction elements were developed. Wireframes, mood boards, and mock-ups were built to arrange the presentation of AR flower models, information panels, and navigation while maintaining an engaging, user-friendly experience.

Development phase: the design concepts were turned into a functioning AR application, including the creation of five 3D Malaysian flower models (hibiscus, Rafflesia, orchid, rose, and sunflower) with interactive anatomical labels for structures such as petals, sepals, stamens, and pistils, alongside ongoing testing to improve performance, usability, and visual quality.

Implementation phase: the completed application was made available to users via mobile devices using physical QR-code learning cards. These cards displayed each flower's name, botanical classification, habitat, care guidelines, and cultural significance, and were scanned to trigger the corresponding 3D AR overlay. User interactions were monitored to confirm the application was usable, stable, and useful as a teaching tool.

Evaluation phase: the application's success was assessed through formative and summative evaluation. Testing and user feedback were gathered to assess usability, learning efficiency, engagement, and overall satisfaction, informing areas for future enhancement.

3.4 Testing and Evaluation Protocol

Participants were invited to interact directly with the Learning in Bloom application and the printed QR-code learning cards. They were briefly oriented on how to scan the cards to display the 3D floral models, then allowed to explore the five flower models and read the corresponding information panels at their own pace. Immediately following the session, participants completed the usability questionnaire.

3.5 Data Analysis Methods

Quantitative data from the fifty-one participants' post-interaction questionnaires were compiled and analysed to evaluate the overall effectiveness of the application. Descriptive statistics, expressed as percentage distributions, were calculated to summarise participants' familiarity with local flora, prior exposure to augmented reality, and general interest in interactive botanical education.

4. Results and Findings

4.1 Participant Prior Technology Experience

The evaluation was conducted with fifty-one respondents. Analysis of the survey responses indicated that 56.9% of respondents had previously used an augmented reality application, while 43.1% had no prior exposure to AR tools.

4.2 Baseline Botanical Familiarity

The baseline survey revealed a substantial knowledge gap regarding local flora. Only 31.4% of participants characterised themselves as "very familiar" with Malaysian flower species, while 68.6% expressed a lack of confidence in their local botanical knowledge overall — of whom 60.8% of the total sample described themselves as only "somewhat familiar" and 7.8% as "not familiar". This widespread lack of confidence indicates a baseline knowledge gap that an educational AR application is well placed to address.

4.3 Learner Interest and Pedagogical Preferences

Despite low baseline familiarity, participants showed high interest in botanical education, particularly in interactive and localised formats. A general interest in studying flower species was reported by 70.6% of respondents, rising to 80.4% when the focus was narrowed to Malaysia's unique regional flora, and 86.3% expressed a strong desire to learn about both specific flower varieties and their biological characteristics.

The findings also support the integration of interactive technology into botanical learning: 74.5% of respondents preferred visual and interactive content, and 92.1% reported that studying flowers improved their overall respect for the natural world.

4.4 Summary of Baseline Characteristics

Table 1 summarises the percentage distribution of participant responses across prior technology experience, baseline botanical familiarity, educational interest, learning preference, and ecological attitude.

Table 1

Percentage distribution of participant baseline characteristics and perceptions (N = 51)

Category	Survey Variable	Percentage (%)
Prior technology experience	Have used an Augmented Reality application before	56.9
Prior technology experience	Have not used an Augmented Reality application before	43.1
Botanical familiarity	Very familiar with Malaysian floral species	31.4
Botanical familiarity	Somewhat familiar with Malaysian floral species	60.8
Botanical familiarity	Not familiar with Malaysian floral species	7.8
Botanical familiarity	Lacks deep confidence in local botanical knowledge (total)	68.6
Educational interest	General desire to study various flowers	70.6
Educational interest	Specific desire to study Malaysia's unique flora	80.4
Educational interest	Desire to learn floral varieties and unique biological traits	86.3
Learning preference	Prefer visual and interactive content for botanical education	74.5
Ecological attitude	Believe studying flowers improves respect for the natural world	92.1

4.5 Visual and Application Prototype Output

The primary visual outputs of the study are the physical-to-digital learning interface and the interactive user controls. Figure 1 shows the AR flower-selection screen used to launch the three-

dimensional model for a chosen species. Figure 2 shows development screenshots from the Assembler platform in which labelled anatomical overlays (for example, stem, leaves, and species name) are attached to the rendered 3D flower models. Together, these outputs form the functional core of the Learning in Bloom prototype.

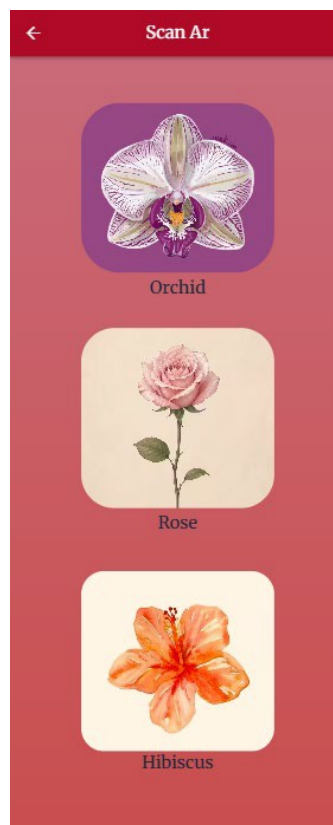
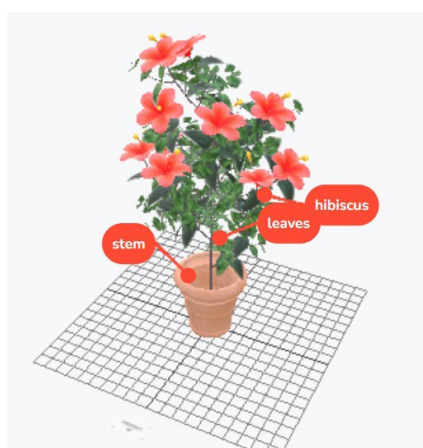
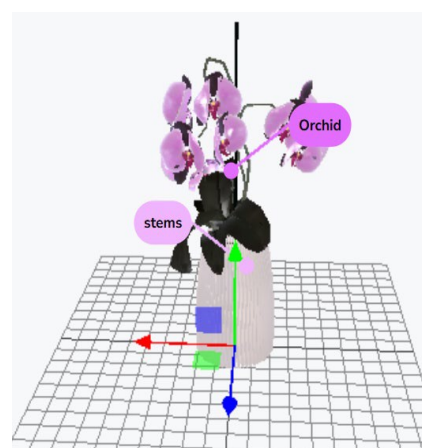


Fig. 1. AR flower-selection screen used to launch the three-dimensional flower model in the Learning in Bloom application



(a)



(b)

Fig. 2. Assembler development screenshots of labelled 3D flower models: (a) hibiscus; (b) orchid

5. Discussion

5.1 Key Findings and Alignment with Research Objectives

The baseline survey revealed a marked knowledge gap, with 68.6% of respondents lacking confidence in their familiarity with native Malaysian flora. This supports the study's rationale, which critiques the traditional Malaysian reliance on passive instructional resources such as textbooks and teacher-centred lectures, and the findings suggest mobile AR is a viable pedagogical tool to address this gap. Using an application that introduced five culturally and ecologically significant flower species, the study found a strong alignment between user preferences and instructional design, evidenced by the 74.5% of participants who preferred visual and interactive layouts.

The application's performance also aligns with the third research objective, which concerned environmental awareness and engagement with local flora: 92.1% of participants reported that studying flowers improved their respect for the natural world, providing evidence that pairing digital technology with botanical instruction can foster pro-environmental attitudes. The manuscript does not, however, present usability or performance metrics broken out separately for the florists and farmers named in Objectives 1 and 2 — the fifty-one respondents were analysed as a single group. Because the results show both a shared baseline knowledge gap and a shared preference for interactive visual content, it is plausible that basic botanical care, habitat, and taxonomic information is broadly accessible across user groups, but this reading is an interpretation rather than a finding directly supported by disaggregated data, and the author should treat it as a proposed explanation to confirm or qualify rather than a settled conclusion.

5.2 Comparative Literature and Theoretical Contextualisation

The baseline botanical unfamiliarity documented here (68.6%) is consistent with wider literature on "plant blindness" [12] and with evidence that modern academic curricula often overlook regional plant awareness in favour of global zoological concepts, contributing to a generational decline in botanical literacy [22]. That 80.4% of participants expressed specific interest in Malaysia's regional flora suggests that localised digital content can activate situational interest, addressing the regional curricular gap noted in earlier work [20].

The strong preference for visual and interactive elements (74.5%) is consistent with prior findings that mAR environments increase student satisfaction, spatial understanding, and interest in science education relative to print materials [1,4]. The inclusion of detailed, interactive structural labels (sepals, petals, stamens, pistils) also addresses a limitation identified in commercial plant-recognition software, which tends to function as a taxonomic "black box" without teaching morphology [13,23]: by pairing physical learning cards with structural 3D overlays, Learning in Bloom moves users from name-retrieval toward active structural learning. The positive environmental attitude reported by 92.1% of respondents is also consistent with evidence that interactive 3D botanical models can deepen learners' emotional connection to biodiversity [24], and the focus on culturally significant species such as the national hibiscus is in line with calls to preserve local traditional ecological knowledge alongside formal instruction [16,20].

5.3 Instructional Design Mechanisms

Several design choices plausibly contributed to the observed preference for the application's visual and interactive format, though the author should treat the following as proposed explanations to confirm rather than established findings:

Physical-to-digital feedback loop: using printed QR-code cards as tactile triggers for the 3D models created a multisensory experience that may have reduced spatial cognitive friction between print description and virtual model.

Labelled morphological visualisation: the interactive anatomical labels on the 3D models, viewable from multiple angles, may have made abstract processes such as pollination and floral structure more visually intuitive, contributing to the 74.5% visual preference.

Culturally contextualised content: framing botanical information within local cultural context (for example, the patriotic symbolism of the hibiscus) may have increased the material's personal relevance, contributing to the 80.4% interest in native species.

5.4 Methodological and Scope Limitations

Sample size and representation: the evaluation used a relatively small cohort of fifty-one respondents, which limits the generalisability of the findings to the broader Malaysian population.

Content and curricular scope: the application's educational content focuses on basic flower facts and does not cover advanced biological, ecological, or environmental-science themes, due to time, resource, and expert-knowledge constraints during development.

Statistical gaps: the methodology describes a paired pre-test/post-test design intended to measure knowledge gains, but the results reported are limited to post-interaction survey percentages — no pre-test scores, comparative averages, or significance statistics (such as a paired-samples t-test) are presented. Learning-efficacy claims are therefore based on self-reported post-interaction perceptions rather than a direct, pre/post measurement of knowledge retention, and this gap should be resolved (either by reporting the pre/post data or by revising the claims) before submission.

Demographic aggregation: the results treat the fifty-one respondents as a single cohort; the manuscript does not present separate data, usage feedback, or challenges for the florists and farmers named specifically in Research Objectives 1 and 2.

6. Conclusion and Future Directions

This study examined how mobile augmented reality can enhance user engagement and pedagogical value while motivating learners to discover Malaysia's floral diversity. Evaluation among fifty-one respondents indicated that the Learning in Bloom application increased user interest, supported comprehension of botanical structure, and offered a more engaging experience than conventional teaching methods. By combining printed instructional cards with interactive three-dimensional models, the application provides a practical foundation for promoting local plant biodiversity and narrowing the regional botanical knowledge gap, bridging digital multimedia technology and environmental education.

The current application is restricted to fundamental botanical facts because of constraints on development time, physical resources, and expert knowledge. Future work should expand the biological content, add interactive quizzes and further multimedia features, and report the pre/post-test data described in the methodology so that learning gains can be evaluated empirically rather than through self-reported perceptions alone.

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