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Converging heutagogy, M-learning, and AI for sustainable language education: A fuzzy Delphi study

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Abstract: This study aimed to develop an expert-validated framework that integrates heutagogy, mobile learning (m-learning), and Artificial Intelligence to create sustainable and future-proof language education. Addressing a significant gap in the existing literature, this research provides the first expert-validated framework detailing how AI functionalities can strategically support each core process of self-determined language learning within a mobile context. The Fuzzy Delphi Method was employed, seeking consensus from a panel of 15 experts in language education, educational technology, and AI design. A three-round iterative process using a 5-point linguistic scale, converted to triangular fuzzy numbers, was used to evaluate proposed framework elements, achieving a consensus threshold of $d \leq 0.2$ and a 75% agreement rate. Findings confirmed strong expert consensus on all core elements, with AI-powered personalization (0.88) identified as crucial for facilitating heutagogy's explore, create, and reflect cycles. Smartphones (0.89) were reaffirmed as the primary m-learning device. Significantly, AI-facilitated peer matching and recommendation systems for "Share" (0.92) received the highest ranking, underscoring AI's value in enhancing human collaboration. The study concludes that this synergistic convergence transforms language education by promoting learner autonomy and equitable access, directly contributing to Sustainable Development Goal 4. The resulting framework provides a practical roadmap for educators and policymakers.
Keywords: *Artificial intelligence, Fuzzy Delphi method, Heutagogy, Language education, Mobile learning,*

1. Introduction

The global educational landscape is undergoing a profound transformation, driven by rapid technological advancement and a pressing need for sustainable development models [1]. Within this context, language education faces a dual challenge: it must not only adapt to new digital paradigms but also remain relevant and effective in fostering the skills necessary for lifelong learning and global citizenship. The United Nations Sustainable Development Goal 4 (SDG 4) explicitly calls for ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all by 2030 [1]. This global imperative is echoed by international bodies. The OECD [2] emphasizes the urgent need for education systems to evolve beyond knowledge transmission to fostering skills like critical thinking, adaptability, and self-regulation, while UNESCO [3] advocates for the strategic use of digital technologies to expand access and personalize learning. Achieving these ambitious goals requires moving beyond traditional pedagogical models towards innovative, flexible, and learner-centric approaches. The concept of lifelong learning has become a cornerstone of national educational strategies worldwide. For instance, Malaysia's Education Blueprint 2015-2025 emphasises creating a "Nation of Lifelong Learners" [4] a vision shared by numerous other national strategies. For working adults and non-traditional students, flexibility and accessibility are paramount. Mobile learning (m-learning) has emerged as a powerful tool in this endeavour. Smartphones, in particular, have been identified as the most suitable device for facilitating learning anytime and anywhere due to their ubiquity and connectivity [5, 6]. However, the mere use of technology is insufficient; it must be guided by a robust pedagogical framework. Heutagogy, or self-determined learning, provides such a framework [7]. It empowers learners to be the primary agents in their learning process, focusing on developing learner

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capabilities and competencies through practices of exploration, creation, connection, sharing, reflection, and collaboration [7, 8]. This approach is particularly well-suited for lifelong learners who must navigate complex and ever-changing information landscapes. As argued in Blaschke [9] for heutagogy to be successful, learning environments must be deliberately designed to offer both the freedom for self-direction and the supportive structures that empower learners to navigate it effectively. The next logical step in this evolution is the integration of Artificial Intelligence (AI). AI has the potential to radically personalise the learning experience, offering adaptive content, intelligent tutoring systems, and automated feedback that can scaffold the self-determined learning process [10, 11]. It can analyse a learner's progress in real-time, suggest personalised resources for "exploration," and connect learners with collaborative partners. This convergence of pedagogy (heutagogy), technology (m-learning), and innovation (AI) presents a transformative opportunity to future-proof language education making it more adaptive, efficient, and sustainable on a global scale. However, the practical design and implementation of such an integrated model remain undefined. While the synergy is theorized [12] there is a lack of empirical validation and a detailed, expert-validated framework. What specific AI functionalities should be designed to directly support each core process of the heutagogical cycle within a mobile context? To answer this question, this study employs the Fuzzy Delphi Method (FDM) to achieve a consensus among experts. The aim is to develop a validated framework that provides a clear roadmap for designing equitable, engaging, and sustainable future proof language education system.

2. Literature Review

2.1. Heutagogy: The Foundation of Self-Determined Learning

Heutagogy, a concept pioneered by Ouyang and Jiao [7] extends beyond andragogy by placing the learner as the absolute central agent in the educational process. It is characterized by self-determined learning, where learners are not just involved in how they learn but also in what they learn and why it is meaningful to them [8]. This approach is fundamental for developing capabilities such as critical thinking, adaptability, and creativity, which are essential for navigating the complexities of the modern world [13]. The application of heutagogy is operationalized through a cycle of practices: explore, create, connect, share, reflect, and collaborate [14]. In the context of language learning, this could mean a learner choosing to explore Spanish cinema on YouTube, create a blog post reviewing a film, share it with a learning community, reflect on feedback received, and collaborate on a project with a peer. This process fosters deep, intrinsic motivation and moves the role of the educator from a transmitter of knowledge to a facilitator and guide [15]. However, a significant challenge in implementing pure heutagogy is the potential for learner overwhelm and a lack of structure, which can hinder progress and lead to disengagement [16]. This underscores the need for sophisticated technological scaffolding to make self-determined learning effective and sustainable. Recent work by Blaschke [9] emphasizes that for heutagogy to be successfully enacted, learning environments must be deliberately designed to offer both the freedom for self-direction and the supportive structures that empower learners to navigate it effectively.

2.2. Mobile Learning (M-Learning) as an Enabling Tool

M-learning, defined as learning across multiple contexts through social and content interactions using personal electronic devices [17] is the ideal technological counterpart to heutagogy. Its inherent characteristics portability, accessibility, connectivity, and context sensitivity provide the flexibility required for self-determined learning to flourish outside traditional classroom settings [18].

Studies have consistently shown that smartphones, in particular, are the most accessible and prevalent device for lifelong learners, effectively breaking down barriers of time and location [6, 19]. A systematic review by Crompton and Burke [5] confirms the primacy of smartphones in higher education, highlighting their ubiquity as a key driver for mobile learning adoption. Recent research on the Malaysian freelance sector confirms that infrastructural deficiencies and the high cost of AI tools remain significant barriers, particularly for virtual assistants (VAs) in rural areas, preventing them from leveraging mobile and AI technologies effectively [20]. However, Crompton and Burke [5] also note that many m-learning initiatives still lack pedagogical depth, often focusing on content delivery rather than leveraging the mobile device's unique affordances for collaboration and creation. For language acquisition, m-learning facilitates authentic engagement through access to native media, language apps, and communication tools, allowing for micro-learning moments that can be seamlessly integrated into daily life [21]. Yet, the field often focuses on accessibility rather than pedagogical depth. Many m-learning applications remain stuck in a behaviourist paradigm of drill and practice, failing to leverage the full potential of mobile devices for collaboration, creation, and connected learning [22].

2.3. The Transformative Potential of Artificial Intelligence (AI)

Artificial Intelligence in education (AIEd) refers to the use of AI technologies to support, enhance, and personalize learning. AI's potential lies in its ability to analyze vast amounts of learner data to provide intelligent, adaptive, and personalized experiences Kamrozzaman, et al. [23]. Adler and Ziglio [11] categorize these applications into three paradigms: AI-directed such as intelligent tutoring systems, AI-supported such as automated feedback tools, and AI-empowered such as environments that foster human-AI collaboration to enhance metacognition). In language learning, AI-powered tools can offer:

- Intelligent Tutoring Systems (AI-directed): Providing instant, personalized feedback on pronunciation, grammar, and writing.
- Adaptive Learning Paths (AI-directed): Dynamically adjusting the difficulty and type of content based on a learner's performance and goals.
- Natural Language Processing (NLP) (AI-supported): Enabling conversational practice with chatbots that can simulate real-world interactions.
- Automated Analytics (AI-supported): Giving learners and educators deep insights into progress patterns and areas needing improvement.

The recent advent of generative AI has significantly expanded these possibilities, moving beyond adaptive systems to co-creative partners that can generate learning materials, scenarios, and dialogue practices tailored to a learner's interests and level [10]. Despite this transformative potential, the adoption of AI is not without significant challenges. These include concerns over privacy, data security, ethical implications such as algorithmic bias, and the risk of over-reliance, which can negatively impact critical thinking skills [24]. Furthermore, a lack of understanding and awareness of how to use AI tools effectively presents a major hurdle for many potential users. However, despite this potential, current AIEd applications are frequently critiqued for their narrow focus. As noted by Kukulska-Hulme, et al. [25] the majority of AI in education research is focused on automated assessment and adaptive systems (the AI-directed paradigm), which, while useful, often operate in a pedagogical vacuum. They are typically designed for individual consumption rather than social constructivist or connectivist learning. This siloed approach means AI's power to foster human connection, mediate collaboration, and support metacognition the very pillars of heutagogy remains largely untapped [26, 27].

2.4. Converging the Three Pillars for Sustainable Language Education

While each of these domains heutagogy, m-learning, and AI has been studied independently, their convergence remains a nascent yet highly promising field. Heutagogy provides the pedagogical philosophy, m-learning provides the ubiquitous access, and AI provides the sophisticated, personalized engine to make self-determined learning truly scalable and effective. For instance, an AI system can recommend resources for a learner to explore based on their interests and current level (e.g., suggesting a beginner-friendly podcast after detecting struggles with listening comprehension). It can then provide the tools to create a summary of that podcast and connect the learner with a peer who is working on a similar topic. This creates a powerful, synergistic cycle that amplifies the benefits of each individual component. Preliminary conceptual work, such as that by Agonacs and Matos [12] suggests this synergy is powerful, but it remains largely theoretical without empirical validation or a detailed design framework.

2.5. Research Gap

Previous research has established the validity of using the Fuzzy Delphi Method (FDM) to achieve expert consensus on educational frameworks [28, 29]. It has also confirmed the suitability of heutagogical elements and m-learning devices for general education [6]. However, a significant and persistent gap exists in the literature. While studies have explored these concepts in isolation, no study has yet developed an expert-validated model that details how AI functionalities should be strategically designed to directly

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scaffold and enhance each core process of the heutagogical cycle (explore, create, connect, share, reflect, collaborate) within a mobile learning context for language education.

Therefore, this study aims to fill this critical gap by seeking expert consensus to define and prioritize the elements of a framework that strategically converges heutagogy, m-learning, and AI to future-proof language education for sustainable development.

3. Method

This study employed a quantitative design utilizing the Fuzzy Delphi Method (FDM) to obtain a consensus from a panel of experts on the critical elements for integrating heutagogy, m-learning, and AI in language education. The FDM is a robust technique that incorporates fuzzy set theory into the traditional Delphi method, effectively handling the ambiguity and subjectivity of human expert judgment [30]. This method was selected for its ability to generate reliable consensus in a single round, saving time and resources while reducing the vagueness often associated with qualitative expert opinions [28, 29].

3.1. Instrumentation

The primary instrument for this study was a questionnaire developed based on a comprehensive review of literature on heutagogy [8, 14] m-learning [17, 18] and AI in education. The questionnaire was divided into two main sections:

- Section A: Demographic profile of the experts (field of expertise, years of experience, academic qualification).
- Section B: Elements for the framework. This section presented a list of potential items across three categories: (1) Heutagogical Practices, (2) M-Learning Functionalities, and (3) AI-Enabled Features. Experts were asked to evaluate their agreement on the necessity of each item using a 5-point linguistic scale (1=Strongly Disagree, 2=Disagree, 3=Uncertain, 4=Agree, 5=Strongly Agree).

3.2. Expert Panel Selection

The selection of a competent and diverse expert panel is critical to the validity of the FDM. Following the assertions of Park [31] a panel of 15 experts was recruited. These experts were purposively selected based on the following criteria to ensure a holistic perspective:

- Language Education (5 experts): Academics with a Ph.D. and over 10 years of experience in language teaching methodology and curriculum development.
- Educational Technology (5 experts): Specialists with a proven research background in m-learning, instructional design, and technology integration in education.
- Artificial Intelligence (5 experts): Professionals or academics with expertise in AI, machine learning, or natural language processing, particularly with applications in learning technologies.

3.3. Data Collection Procedure

The data collection procedure adhered to the established steps of the Fuzzy Delphi technique [32]:

1. Questionnaire Distribution: The questionnaire was distributed to the 15 experts via email, along with a detailed information sheet and consent form.
2. Linguistic Scale Conversion: The experts' responses on the 5-point linguistic scale were converted into Triangular Fuzzy Numbers (TFNs) to capture the range of expert opinions. The conversion used the scale detailed in Table 1.
3. Calculation of Average Fuzzy Numbers: The fuzzy opinions of all experts for each item were aggregated to obtain a single fuzzy number representing the collective judgment (M) for that item, calculated as:

$$M = (m1, m2, m3) = \left(\frac{1}{n} \sum_{i=1}^{n} a_i, \frac{1}{n} \sum_{i=1}^{n} b_i, \frac{1}{n} \sum_{i=1}^{n} c_i \right)$$

where (ai,bi,ci) is the TFN provided by expert ii for an item, and n is the total number of experts.

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Table 1.
5-point Linguistic Scale and Corresponding Triangular Fuzzy Numbers.

Linguistic Variable	Fuzzy Scale (TFN)
Strongly Disagree	(0.00, 0.10, 0.20)
Disagree	(0.10, 0.20, 0.40)
Uncertain	(0.20, 0.40, 0.60)
Agree	(0.40, 0.60, 0.80)
Strongly Agree	(0.60, 0.80, 1.00)

3.4. Data Analysis: Achieving Consensus

The analysis focused on two key criteria to determine expert consensus for each item:

1. Threshold Value (d): The distance between the aggregated fuzzy judgments of the expert group needed to be within the acceptable threshold. The value d represents the degree of agreement among experts. For an item to be accepted, the threshold value must be d ≤ 0.2 [32]. The formula for calculating d is:

$$d = \sqrt{\frac{1}{3}\left[(m1 - n1)^2 + (m2 - n2)^2 + (m3 - n3)^2\right]}$$

(This ensures the expert opinions are sufficiently convergent).

2. Percentage of Consensus **(>75%):** In addition to the threshold, over 75% of the experts' individual fuzzy evaluations for an item must fall within the defined range of agreement (d ≤ 0.2) [20].

Items that failed to meet both of these criteria were discarded from the final framework.

3.5. Defuzzification and Ranking of Items

For items that achieved consensus, a defuzzification process was applied to convert the aggregated fuzzy number (M) into a crisp, quantifiable value (A). This value allowed for the ranking of all accepted items by their importance, as perceived by the expert panel. The method of Centre of Gravity (COG), a common and effective defuzzification technique, was used with the following formula:

$$A = \frac{(m1 + m2 + m3)}{3}$$

A higher defuzzification value (A) indicates a higher level of agreement and perceived importance of the item by the expert panel. The items were then ranked from highest to lowest based on this value.

4. Findings and Results

This study successfully obtained a strong consensus from the panel of 15 experts on the critical elements for integrating heutagogy, m-learning, and AI in language education. The findings are presented in two parts: the demographic profile of the expert panel and the results of the Fuzzy Delphi analysis for the proposed framework elements.

4.1. Demographic Profile of Experts

The panel consisted of 15 experts purposively selected from three distinct but complementary fields to ensure a comprehensive and balanced perspective. Their distribution is summarized in Table 2.

Table 2.
Distribution of Experts by Field of Expertise.

Field of Expertise	Number of Experts	Percentage (%)
Language Education	5	33.3
Educational Technology	5	33.3
Artificial Intelligence	5	33.3
Total	**15**	**100.0**

All experts held a doctoral degree (Ph.D.) in their respective fields and had an average of 12.7 years of relevant professional and research experience, ensuring a high level of competency in their evaluations.

4.2. Expert Consensus on Framework Elements

The analysis of the expert evaluations yielded a strong consensus. The overall percentage of items achieving the threshold value of d ≤ 0.2 was 96.4%, far exceeding the required 75% benchmark. This indicates a very high level of agreement among the experts on the importance of the proposed elements.

4.2.1. Priority of M-Learning Devices

Experts were asked to evaluate the suitability of various devices for the proposed framework. The results, including the percentage of consensus for each device, their average defuzzification score, and final ranking, are presented in Table 3. The defuzzification score (A) ranges from 0 to 1, with a higher score indicating higher perceived importance and agreement.

Table 3.
Fuzzy Delphi Analysis: Consensus and Ranking of M-Learning Devices.

Device	Expert Consensus (%)	Avg. Defuzzification Score (A)	Ranking
Smartphone	100	0.89	1
Tablet	93.3	0.76	2
Laptop	86.7	0.68	3

4.2.2. Ranking of Integrated Heutagogy-AI Elements

The core of the analysis focused on evaluating how AI could specifically enhance each of the core heutagogical practices. The results, presented in Table 4, show the ranking of these integrated elements based on their average defuzzification scores, which reflect their perceived necessity and impact as determined by the expert panel.

Table 4.
Ranking of Integrated Heutagogy-AI Elements by Expert Consensus.

Heutagogical Element	AI-Enabled Functionality	Avg. Defuzzification Score (A)	Ranking
Share	AI-facilitated peer matching and recommendation systems for forming learning pods based on complementary skills and goals.	0.92	1
Explore	An AI-powered, personalized recommendation engine for learning resources (articles, videos, podcasts) tailored to the learner's level and interests.	0.88	2
Reflect	AI-generated analytics dashboards that provide learners with visual insights into their progress, strengths, and areas for improvement.	0.85	3
Create	AI-assisted tools for content creation, such as grammar and style checkers for writing, or pronunciation feedback for speaking exercises.	0.83	4
Collaborate	AI-mediated collaboration tools that suggest roles in group projects or translate messages in real-time to overcome language barriers.	0.80	5
Connect	AI-driven forums and community platforms that connect learners with native speakers and mentors based on learning objectives.	0.78	6

The element "Share" integrated with AI-powered peer matching received the highest ranking (A=0.92), underscoring the experts' view that facilitating effective collaboration is the most valuable application of AI in a self-determined learning context. This is followed closely by AI for personalized exploration of content (A=0.88) and AI for supporting self-reflection (A=0.85).

All elements achieved a consensus percentage above 87%, confirming their validity and necessity within the proposed framework for future-proofing language education.

5. Discussion

This study successfully achieved a strong expert consensus on the core elements of a framework that converges heutagogy, m-learning, and AI to future-proof language education. The findings not only validate the proposed model but also offer a prioritized roadmap for its implementation, with significant implications for achieving sustainable educational development.

5.1. The Primacy of the Smartphone as a Gateway to Learning

The unanimous consensus (100%) identifying the smartphone as the most suitable device for this framework (A=0.89) powerfully reinforces existing literature. This finding is corroborated by recent research in the Malaysian context, which identified smartphones as the primary device for freelance virtual assistants, highlighting their critical role as a gateway to digital work and learning, especially in areas with limited other resources Jamil, et al. [20]. Bozkurt [6] and Glassner [18] who highlighted its ubiquity, portability, and accessibility. For the lifelong learner balancing education with work and personal commitment the smartphone is the most practical and democratic tool. It ensures that high-quality, AI-powered language learning is not confined to a desktop or a specific location but is truly integrated into the daily fabric of the learner's life, a core tenet of both m-learning [17] and sustainable, equitable education (SDG 4) [1].

5.2. The Centrality of "Share" in an AI-Enhanced Heutagogical Model

The most significant finding of this study is the highest ranking of the "Share" element when augmented by AI (A=0.92). This suggests that experts perceive the greatest value of AI not in solitary learning tasks, but in its ability to *mediate and enhance human collaboration*. This extends Blaschke [14] original concept of sharing by making it more efficient and effective. An AI that can intelligently match learners based on complementary skills, language levels, and goals (e.g., a learner strong in writing paired with a learner strong in speaking) addresses a critical logistical barrier to collaboration for busy adults. It saves time and creates more productive learning partnerships, directly addressing the time constraints of lifelong learners noted by Selwyn [33]. This transform sharing from a simple activity into a strategically facilitated process of knowledge co-creation. This finding aligns with the future trajectory of mobile learning described by Tee, et al. [34] who posits that the most significant innovation in the field will come from technologies that support connected, collaborative, and contextual learning, moving beyond individual consumption to community-based knowledge building.

5.3. The Synergistic Role of AI in Empowering Self-Determination

The high rankings for "Explore" (A=0.88) and "Reflect" (A=0.85) demonstrate how AI directly empowers the core of heutagogy: learner agency. An AI-powered recommendation engine acts as a personal curator, guiding learners through the overwhelming abundance of online resources. This scaffolds the "explore" phase, making it more focused and effective, and prevents the frustration that can lead to disengagement.

Furthermore, AI's role in "Reflect" is transformative. Traditional self-reflection can be subjective and imprecise. AI-generated analytics provide learners with objective, data-driven insights into their progress example vocabulary growth, grammar accuracy trends, pronunciation improvement. This moves reflection beyond a simple feeling to an informed analysis, enabling learners to make more self-determined decisions about their future learning path. This aligns with the concept of double-loop learning inherent in heutagogy, where learners not only learn but also learn *how to learn* [7].

5.4. A Validated Framework for Sustainable Practice

The strong consensus (96.4% overall) on all elements provides a validated blueprint for developers, educators, and institutions. The framework moves from theory to practice, offering a clear set of priorities:

1. First, build AI systems that connect people (Share).
2. Then, ensure these systems can guide personalized discovery (Explore).
3. Finally, equip learners with data to understand their own journey (Reflect).

This order of priority is crucial for designing engaging and sustainable language learning ecosystems that mitigate dropout rates and foster a sense of community, which is essential for long-term [35].

5.5. Limitations and Future Research

While this study provides a strong foundational model through expert validation, it is not without limitations. The framework is a design blueprint; its efficacy in real-world learning environments needs to be tested through empirical studies with actual learners. Future research should focus on implementing this framework in a functional prototype and conducting longitudinal studies to measure its impact on language proficiency, learner motivation, and retention rates. Furthermore, ethical considerations regarding data privacy, algorithmic bias, and the potential for surveillance in AI-driven learning platforms must be a central focus of subsequent development and research Low and O'Connell [26] and Ministry of Education Malaysia [27]. As Low and O'Connell [26] argues, the adoption of AI in education necessitates a critical dialogue that questions whose interests are served and how power dynamics between the learner, the institution, and the technology platform are managed. Future work must therefore investigate not only the efficacy but also the ethical dimensions of data usage and learner privacy within AI-driven, self-determined learning environments.

6. Conclusion

This study was driven by the imperative to future-proof language education by making it more personal, accessible, and sustainable. In response, it developed and validated a framework for the convergence of three powerful domains: the pedagogical philosophy of heutagogy, the ubiquity of mobile learning, and the transformative potential of Artificial Intelligence. Utilizing the Fuzzy Delphi Method, a strong consensus was achieved from a diverse panel of 15 experts, confirming the critical elements of this integrated model.

The study successfully met its objectives. First, it identified and prioritized the core components of the framework. The findings unequivocally position the smartphone as the central and most suitable device for delivering this model, affirming its role as a gateway to equitable and lifelong learning. Second, and more significantly, the study provided a ranked order of integrated heutagogy-AI elements. The results revealed that the highest priority for experts is not merely using AI for instruction, but leveraging its power to facilitate human connection, with AI-enhanced sharing and collaboration being deemed the most crucial element. This is closely followed by AI-powered exploration and data-driven reflection, highlighting a model where AI primarily serves to empower learner agency and metacognition, the very heart of self-determined learning.

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Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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