

PAPER

Design and Validation of a Mobile Learning-Based PAD Class Module to Support ICT Teaching Competency in Pre-Service EFL Teacher Education: A Fuzzy Delphi Study

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ABSTRACT

This study addressed a critical gap in teacher education concerning the development of information and communication technology (ICT) teaching competency among pre-service English as a foreign language (EFL) teachers. Although mobile learning is widely recognized as an effective instructional approach, its systematic integration into teacher education remains limited. To address this issue, this study developed a novel mobile learning-based Presentation-Assimilation-Discussion (PAD) Class module (ML-PAD) designed to support ICT teaching competency among pre-service EFL teachers. The Fuzzy Delphi method (FDM) was employed to identify and validate the module's key constructs and elements. Twelve experts in EFL pedagogy and educational technology participated in the validation process. Expert consensus was reached on five main constructs and thirty-three elements, including module objectives, module contents, instructional procedures, online platform and tool design, and assessment strategies. The findings indicate that experts considered the proposed ML-PAD module pedagogically appropriate and contextually relevant to the Chinese EFL teacher education context. The ML-PAD module may provide useful design references for similar teacher education settings, while further empirical validation in other educational contexts remains necessary.

KEYWORDS

mobile learning, Presentation-Assimilation-Discussion (PAD) Class model, information and communication technology (ICT) teaching competency, pre-service EFL teachers, teacher education

1 INTRODUCTION

The rapid advancement of information and communication technologies (ICT) and the growing emphasis on digital competencies in global education have placed significant demands on teacher education programs. According to the United Nation's

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Sustainable Development Goals [1], cultivating digital literacy and ICT teaching competency in pre-service teachers is essential for achieving high-quality education and improving students' learning outcomes in a technology-driven society. To address this need, various frameworks have been proposed, such as UNESCO's ICT Competency Framework for Teachers [2], the TPACK model [3], the European Commission's DigCompEdu framework [4], and China's ICT Teaching Competency Standards for Pre-service Teachers [5]. These models provide theoretical foundations for understanding and assessing teachers' ICT teaching competency. However, most existing studies focus on defining and evaluating competency rather than on designing pedagogical modules that can effectively cultivate such abilities in authentic teaching contexts. This gap highlights the need to design and develop innovative, practice-oriented modules to support ICT teaching competency development among pre-service teachers.

Mobile learning has increasingly been adopted in teacher education to support teachers' professional development by offering flexible and interactive learning experiences through mobile devices such as smartphones, tablets, and laptops. Grounded in constructivism and learner-centered learning theories, mobile learning supports self-directed, collaborative, and reflective learning [6], which are key processes in the professional growth of pre-service teachers [7]. It has been shown to support the development of pre-service teachers' digital competencies and professional growth [8]. Although some studies have developed online lessons and educational technology tools in online learning [9], most existing studies have focused on cultivating the knowledge, skills, and attitudes of pre-service teachers [10], rather than on the instructional design of modules specifically targeting ICT teaching competency in pre-service teacher education. Research directly addressing how mobile learning can be systematically integrated into pedagogical module design for ICT teaching competency development remains limited.

This study aims to fill the gap by designing a mobile learning-based pedagogical module. Moya and Camacho [11] noted that current research on mobile learning implementation often lacks innovative teaching methods. Therefore, a novel integration of mobile learning and the Presentation-Assimilation-Discussion (PAD) Class model, termed the ML-PAD module, was developed in this study. The PAD Class model is incorporated as the pedagogical framework of the ML-PAD module, guiding its instructional design. Previous studies have shown that the PAD Class model can facilitate active knowledge construction and competence development, which aligns with the development of ICT teaching competency. The PAD Class model integrates well with mobile learning, following clear and structured procedures: presentation, assimilation, and discussion. In the presentation stage, teachers introduce ICT teaching-related instructional knowledge in a structured manner. During the assimilation stage, students engage in reading, reviewing, independent thinking, and completing assignments independently, using mobile devices to access various digital resources and monitor their learning progress. In the discussion stage, a delayed discussion is conducted after students have internalized the content through independent study, while mobile learning facilitates collaboration, knowledge sharing, and reflection, allowing students to track their learning progress [12].

To date, few studies have explored the integration of the PAD Class model and mobile learning, and even fewer have applied it to ICT teaching competency education. Building on the above gaps in teacher education, this study focuses specifically on pre-service English as a foreign language (EFL) teachers, who represent a key subgroup within pre-service teacher education, due to the pedagogical and technological demands of ICT integration in language teaching contexts. This study contributes to the design of the ML-PAD module. Grounded in the PAD Class model and incorporating expert consensus on the elements and constructs, the ML-PAD module provides

valuable reference and guidance for teacher education programs focused on ICT teaching competency. By leveraging mobile learning as an innovative pedagogical method, this module may offer a structured framework for supporting ICT teaching competency development among pre-service EFL teachers. The ML-PAD module also contributes to ongoing discussions on technology-integrated teacher education and may provide useful implications for future instructional design and research.

2 LITERATURE REVIEW

This section introduces the two primary theoretical foundations of the ML-PAD module: Mobile Learning and the PAD Class model.

2.1 Mobile learning

Over the past decade, mobile learning has evolved from a novel technological trend into an increasingly important component of contemporary pedagogy, with widespread implementation across diverse educational contexts. Scholarly definitions of the concept vary: Traxler and Kukulska-Hulme [13] characterize mobile learning as educational provision centered on handheld devices, whereas Crompton and Burke [14] conceptualize mobile learning as learning across multiple contexts through social and content interactions supported by personal digital technologies. Such devices typically include smartphones, tablets, and other portable media tools [15]. Learners utilize these devices to enable both formal (instructor-led) and informal (self-directed) learning processes [16], [17]. This dual affordance highlights the potential of mobile learning to bridge structured classroom instruction with flexible, learner-centered experiences.

However, existing research on mobile learning reveals several persistent limitations. At the pedagogical level, mobile learning implementations often emphasize technological accessibility and content delivery rather than pedagogical integration, which may result in fragmented learning experiences. In addition, a lack of innovative and well-structured instructional design frameworks further constrains the effectiveness of mobile learning environments [11]. At the teacher level, although mobile technologies have demonstrated potential in enhancing teachers' digital competence, limited attention has been paid to how such approaches can systematically support the development of teachers' ICT teaching competency, particularly among pre-service teachers [18]. At the research level, mobile learning studies remain predominantly quantitative, leaving qualitative and mixed-method approaches underrepresented, thereby limiting a deeper understanding of pedagogical processes and model development [19]. These limitations collectively highlight the need for a structured pedagogical model that can effectively integrate mobile learning with instructional design while supporting the development of teachers' ICT teaching competency.

2.2 PAD Class model

The Presentation-Assimilation-Discussion Class model is a teaching paradigm for classroom teaching that combines the strengths of teacher-led instruction and student-centered interaction [20]. Proposed by Zhang [21], the model aims to address common challenges in traditional classrooms, such as insufficient teacher-student interaction and passive student learning. Over the past decade, the model has been widely adopted across higher education in China [20], demonstrating its practical feasibility across diverse disciplines. Figure 1 shows the basic process of the PAD Class.

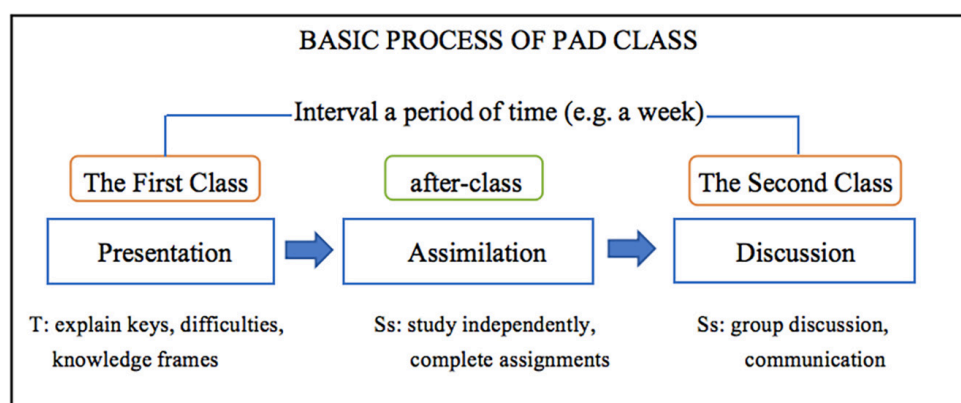


Fig. 1. Basic process of PAD Class

The PAD Class model organizes the teaching and learning process into three sequential stages: presentation, assimilation, and discussion. The core tenet of the PAD Class is to allocate roughly half of the class time to teacher-led presentations while allocating the other half to student-led discussion. Crucially, these two segments are temporally separated to ensure students have sufficient intervals for self-directed study and personalized knowledge internalization [20].

During the presentation stage, instructors provide concise and structured guidance, focusing on key concepts and learning frameworks rather than exhaustive explanations. This approach provides students with a macroscopic roadmap of what, why, and how to learn. The assimilation stage allows students to engage in independent study and targeted assignments, facilitating personalized knowledge internalization. This phase serves as a critical bridge between initial presentation and subsequent discussion, enabling instructors to monitor students' cognitive processes while promoting deeper understanding [21]. In the discussion stage, students participate in structured collaborative activities, including group discussion, selective testing, open Q&A, and an instructor-led summary. Unlike immediate discussion in conventional classrooms, the PAD Class adopts a "delayed discussion" approach, ensuring that students engage in meaningful exchanges after sufficient preparation. Through this staged design, the PAD Class provides continuous pedagogical scaffolding and supports the integration of individual learning and collaborative engagement [22].

A growing body of empirical studies has reported positive outcomes of the PAD Class model in promoting students' learning outcomes. Previous studies have demonstrated its positive impact on academic performance, disciplinary competencies, and higher-order skills such as critical thinking and collaboration [23]–[25]. In the context of teacher education, the PAD Class model has been reported to contribute to the professional development of pre-service teachers, supporting their readiness to meet instructional demands [25].

Although the PAD Class model originated in the Chinese educational context, its pedagogical structure aligns closely with the constructivist principles underpinning the flipped classroom, including an emphasis on learner autonomy, knowledge construction, and interactive learning [26], [27]. However, despite these commonalities, important differences exist in their implementation.

In traditional flipped classroom implementations, learning is heavily dependent on students' pre-class preparation, often requiring high levels of self-regulation and access to technological resources. Empirical studies have shown that many learners struggle to engage effectively with pre-class materials, leading to reduced participation in subsequent classroom activities [28]. Moreover, even in mobile-assisted

flipped contexts, students may encounter technical, pedagogical, and psychological barriers during independent learning, which can hinder the transition to collaborative engagement [29]. In some cases, maintaining effective interaction in flipped environments requires sophisticated AI-supported systems, increasing both technological demands and instructional complexity [30].

In contrast, the PAD Class model addresses these challenges by restructuring the learning process through its staged design. In particular, the assimilation phase reduces reliance on unguided pre-class preparation and provides structured support for knowledge internalization. At the same time, the integration of guided instruction and collaborative discussion facilitates a smoother transition from individual understanding to classroom interaction. Compared with flipped classroom approaches that heavily depend on learner autonomy and technological support, the PAD Class model provides a more pedagogically structured and accessible framework for sustaining student engagement. Therefore, the PAD Class model represents not only a context-specific innovation but also a pedagogically transferable model with potential relevance for international educational settings.

Despite the positive findings reported in previous studies, existing research on the PAD Class model has primarily focused on general learning outcomes, with limited attention to its role in developing teachers' ICT teaching competencies. Furthermore, the integration of the PAD Class model and mobile learning within a teacher education context remains underexplored. To address these gaps, the present study integrates the PAD Class model with mobile learning to develop an innovative ML-PAD module, aiming to support the development of pre-service EFL teachers' ICT teaching competency in diverse digital environments.

3 RESEARCH OBJECTIVES

The present study aims to design and validate a mobile learning-based PAD Class module (ML-PAD) through the application of the FDM. Specifically, it pursues two main objectives: (1) to validate the module constructs and elements through expert consensus, and (2) to develop an ML-PAD prototype for future implementation aimed at supporting pre-service EFL teachers' ICT teaching competency development. Accordingly, the central research question guiding this study is: What is the expert consensus regarding the constructs and elements of the ML-PAD module?

4 METHODOLOGY

4.1 Research design

The Fuzzy Delphi method was employed in the study to identify the key components and overall structure of the ML-PAD module through expert consensus. A total of twelve experts in PAD Class, Mobile learning, curriculum and pedagogy, pre-service teacher education, and the FDM participated in this process. In the initial phase, semi-structured interviews were conducted with four of these experts to define the constructs for the FDM questionnaire. This finalized FDM questionnaire examined expert perspectives on the ML-PAD module in terms of module objectives, content structure, online platform and tools design, instructional procedures, and assessment strategies. Following data collection, expert evaluations were analyzed using triangular fuzzy numbers and the defuzzification technique to quantify responses and assess consensus levels. This approach helped address the ambiguity

and uncertainty inherent in expert judgments, enabling the systematic aggregation and evaluation of the importance and necessity of each construct.

The FDM is an extension of the traditional Delphi method, designed to quantify fuzzy information and achieve expert consensus through iterative feedback. It is particularly suitable for addressing decision-making problems that involve subjectivity, ambiguity, or multiple evaluation criteria [31].

The selection of the FDM was primarily due to its ability to refine expert opinions through rounds of feedback and fuzzy mathematical computations, ultimately converging toward a high level of consensus [32]. Compared with the traditional Delphi method, the FDM retains the strengths of expert consensus-building while integrating fuzzy set theory to better capture the uncertainty and subjectivity commonly present in expert evaluations [31]. This integration contributes to the reliability and validity of the research findings, while the use of domain experts ensures the authority and professional relevance of the collected data [33]. This suitability is further evidenced by [17], who successfully employed FDM to develop a mobile-assisted language learning module.

In this study, the Fuzzy Delphi process was concluded after one round due to the high degree of expert consensus observed. Consensus was defined using three rigorous criteria established in the FDM literature: (1) a threshold value ($d \leq 0.2$); (2) a percentage of expert consensus $\geq 75\%$; and (3) a fuzzy score ($A \geq 0.5$). The results showed that 33 out of 37 items met these criteria, indicating that most of the core components of the ML-PAD module had achieved a stable level of agreement. The four items that did not meet these criteria were either revised or removed based on qualitative expert feedback to ensure the final module's pedagogical rigor.

Although multiple rounds are typical in Delphi studies, previous methodological studies have suggested that multiple rounds are not always necessary when a high level of consensus is achieved in the initial round [34], [35]. In the present study, the high percentage of qualifying items, together with the low dispersion of scores ($d \leq 0.2$), suggests that expert opinions had already reached a stable convergence. Therefore, concluding the process after the first round was considered methodologically acceptable for this design-validation stage and provided an initial expert-validated basis for the ML-PAD module. Nevertheless, the resulting consensus should be interpreted within the Chinese EFL teacher education context, and the transferability of the validated module to other educational settings requires further empirical examination.

This study followed the four major stages proposed by [36], namely: (1) expert selection and questionnaire design, (2) screening, (3) fuzzy conversion and threshold determination, and (4) defuzzification and consensus decision-making. In the first stage, a comprehensive literature review on mobile learning and the PAD Class model, along with semi-structured interviews, was conducted to establish a solid theoretical foundation for the subsequent research stages. Regarding the academic and professional expertise, a panel of twelve experts was then selected. Semi-structured interviews with four of these experts were conducted to collect suggestions on the key elements and overall structure of the ML-PAD module. Drawing on the interview results, an initial questionnaire was developed, further refined based on feedback from three additional experts, and eventually confirmed for the FDM administration.

The second stage, screening, involved distributing the FDM questionnaires to all 12 experts and collecting their responses. Data aggregation and defuzzification were conducted to determine the necessity of further iterations.

In the Fuzzy conversion and threshold determination stage, the fuzzy values obtained during the screening stage were aggregated and analyzed to identify patterns and predict areas of consensus.

Finally, in the last stage of decision-making, expert consensus was synthesized to produce the prototype of the ML-PAD module.

4.2 Participants

The participants of the study involved a panel of twelve experts, including 5 males and 7 females. Purposive sampling was used to identify and recruit experts based on their qualifications and specialized knowledge in the relevant fields. This group size fulfills the methodological requirement of at least ten experts to ensure statistical stability in Fuzzy Delphi research [37]. Consistent with the selection criteria proposed by [38], all participants held advanced academic degrees (25% doctoral degrees; 75% master's degrees). In terms of seniority, 50% of the panel ($n = 6$) had more than 20 years of experience, while the others had between 10 and 20 years of professional practice in EFL pedagogy, the PAD Class model, mobile learning, and pre-service teacher education. Table 1 displays the demographic information of the participants in this study.

Table 1. Experts' demographic information

Category	Item	Frequency
Gender	Male	5
	Female	7
Level of education	PhD degree	3
	Master's degree	9
Work experience	Over 20 years	6
	16–20 years	3
	Under 15 years	3
Position	Professor	3
	Associate Professor	6
	Lecturer	3
Field of expertise	FDM	4
	PAD Class	5
	Mobile Learning	8
	Curriculum and pedagogy	12
	Pre-service teacher education	9
Organization	Gannan Normal University	1
	Fujian Normal University	1
	Science and Technology College of Gannan Normal University	6
	Minnan Normal University	1
	Gannan Science and Technology College	3
Academic Recognition	Active International Peer Reviewers	4
	Others	8

While the experts were recruited from normal universities and teacher education institutions in southern China, including Jiangxi and Fujian provinces, it should be noted that the panel remained geographically and contextually concentrated within this specific educational setting. Although four experts (33.3%) had

experience serving as reviewers for international peer-reviewed journals, this experience should not be interpreted as compensating for the limited geographical and contextual diversity of the panel. Therefore, the expert consensus generated through the Fuzzy Delphi process should be regarded as context-specific and reflective of the Chinese EFL teacher education context. The validated ML-PAD module may provide useful design references for similar teacher education settings, while its transferability to other educational contexts requires further empirical examination.

4.3 Instrument validity and reliability

Two instruments were used in this study for data collection: semi-structured interviews and a Fuzzy Delphi questionnaire.

In the first phase, individual face-to-face semi-structured interviews were conducted with four field experts to gather their opinions on the design of the ML-PAD module. The interviews were audio-recorded, transcribed verbatim, and subjected to member checking, whereby the transcripts were returned to the participants for validation. Thematic analysis was then performed. The emergent themes informed the development of the constructs and the content of the subsequent FDM questionnaire. The FDM questionnaire was carefully designed based on insights gained from the expert interviews and subsequently reviewed by the same four experts to ensure its content validity and relevance. The final version of the questionnaire adopted a five-point Likert-type scale to capture the degree of experts' agreement, preference, or certainty regarding each item. It was structured around five core dimensions: (1) module objectives, (2) module contents, (3) online platform and tools design, (4) instructional procedures, and (5) assessment strategies.

In the second phase, the finalized questionnaire was distributed to the twelve experts with relevant expertise to collect their judgments through the FDM, ensuring the aggregation of expert consensus within the identified dimensions.

4.4 Data analysis

The FDM questionnaire was administered to a panel of twelve experts. The collected data were analyzed using the triangular fuzzy number technique and subsequent defuzzification. Responses expressed on the Likert scale were transformed into triangular fuzzy numbers, as illustrated in Table 2. Each triangular fuzzy number consists of three values: m_1 (minimum), m_2 (medium), and m_3 (maximum), forming a triangular representation of the experts' judgments (see Figure 2).

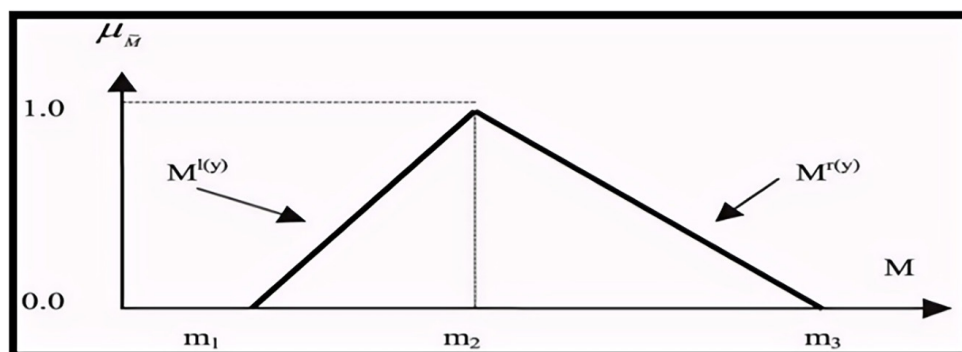


Fig. 2. The mean triangle graph in FDM

Table 2. Fuzzy scale used in this study

Likert Scale	Linguistic Variable	Fuzzy Scale
1	Strongly disagree	(0.0, 0.1, 0.2)
2	Disagree	(0.0, 0.2, 0.4)
3	Partially agree	(0.2, 0.4, 0.6)
4	Agree	(0.4, 0.6, 0.8)
5	Strongly agree	(0.6, 0.8, 1.0)

In the FDM, two conditions must be satisfied for an item to be accepted [39]. First, the threshold value (d) should be less than or equal to 0.2, calculated using the following formula:

$$d(\tilde{m}, \tilde{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]}$$

Second, the consensus level among the experts should exceed 75%. The defuzzification process was carried out using an α -cut value (0.5) [32]. The defuzzified value A was computed using the equation:

$$A = (1/3) * (m_1 + m_2 + m_3)$$

If $A \geq 0.5$, the item is considered acceptable; otherwise, it is rejected. The data analysis was performed using Microsoft Excel in combination with a specialized computation tool (Fuzzy Delphi Analysis v2.0) [40]. The tool automatically computed the threshold value (d), consensus percentage, and defuzzified value to assess expert agreement.

5 RESULTS

The FDM questionnaire results were organized into five sections: module objectives, module contents, online platform and tools design, instructional procedures, and assessment strategies. The following sections present the findings for each dimension of the study.

5.1 Expert consensus on the module objective elements

The module objective elements consisted of eight items aimed at formulating the objectives of the ML-PAD module. Table 3 summarizes the threshold values (d), expert consensus percentages, defuzzification values, and item rankings for all elements based on the experts' consensus. Except for Item 4, all items achieved an expert consensus percentage exceeding 75% and a threshold value (d) below 0.2, indicating a strong agreement among the experts. Item 3 (Improving instructional design skills for EFL teaching) and Item 5 (Enhancing EFL teaching practice ability) ranked the highest, each with a defuzzification value of 0.783, followed by Item 1 (Gaining knowledge of EFL teaching theories) and Item 2 (Gaining knowledge of EFL teaching methods), both with a defuzzification value of 0.767. Subsequently, Item 6 had a

defuzzification value of 0.700, Item 7 recorded a value of 0.717, and Item 8 recorded a value of 0.683. However, Item 4 (Improving skills for making teaching courseware for EFL teaching) was rejected, as its threshold value was 0.212, which exceeded 0.2. Therefore, seven items (Items 1, 2, 3, 5, 6, 7, and 8) were accepted as the final objectives for the ML-PAD module design.

Table 3. Expert's views on module objective elements

No.	Teaching Objective	Threshold Value (d)	Percentage of Expert Consensus, %	Fuzzy Score (A)	Expert Consensus	Ranking
1	Gain knowledge of EFL teaching theories	0.085	83	.767	ACCEPTED	3
2	Gain knowledge of EFL teaching methods	0.085	83	.767	ACCEPTED	3
3	Improve instructional design skills for EFL teaching	0.047	92	.783	ACCEPTED	1
4	Improve skills in making teaching courseware for EFL teaching	0.212	33	.633	REJECTED	—
5	Enhance EFL teaching practice ability	0.047	92	.783	ACCEPTED	1
6	Enhance the ability to apply ICT in EFL teaching	0.153	100	.700	ACCEPTED	6
7	Enhance the ability to apply ICT to EFL learning	0.149	100	.717	ACCEPTED	5
8	Master ICT in an EFL teaching context	0.178	92	.683	ACCEPTED	7

Notes: Conditions to be met: Triangular Fuzzy Numbers: Threshold value (d) ≤ 0.2 ; Percentage of expert consensus $\geq 75\%$. Defuzzification Process: Fuzzy score (A) $\geq \alpha$ -cut value of 0.5.

5.2 Expert consensus on the module content elements

The module content element contains items to guide the design of the ML-PAD module's instructional contents. Designed to develop the ICT teaching competency of pre-service EFL teachers, the module is intended for a ten-week teacher education course. The content components of the ML-PAD module were closely aligned with the TPACK framework [41], encompassing technological, pedagogical, and content knowledge (CK) domains. Elements such as EFL teaching methods, lesson planning, and classroom management reflect pedagogical knowledge (PK), while grammar, vocabulary, and skills-based teaching embody CK. In addition, components like instructional courseware development and the application of ICT in EFL teaching integrate technological knowledge, representing the intersection of TPK, TCK, and ultimately TPACK. Table 4 presents the threshold values (d), the percentages of expert consensus, defuzzification values, and the rankings of all items in the element, as determined by expert agreement.

All items within the content element were accepted, as each achieved an expert consensus level exceeding 75% and a threshold value (d) below 0.2,

indicating strong agreement among panel members. Among these, Items 4 (Lesson planning) and 9 (Teaching pronunciation) ranked the highest, each with a defuzzification value of 0.783. Therefore, lesson planning and pronunciation teaching will be prioritized.

Table 4. Experts' views on module content elements

No.	Content	Threshold Value (d)	Percentage of Expert Consensus, %	Fuzzy Score (A)	Expert Consensus	Ranking
1	Introduction	0.170	92	.667	ACCEPTED	13
2	Views on language and language learning	0.166	83	.639	ACCEPTED	15
3	EFL teaching methods	0.149	100	.717	ACCEPTED	7
4	Lesson Planning	0.047	100	.783	ACCEPTED	1
5	Classroom management	0.149	100	.717	ACCEPTED	7
6	Instructional Courseware Making	0.191	92	.650	ACCEPTED	14
7	Application of ICT in EFL Teaching	0.178	92	.700	ACCEPTED	10
8	Application of ICT in Learning	0.178	100	.683	ACCEPTED	12
9	Teaching Pronunciation	0.047	92	.783	ACCEPTED	1
10	Teaching Grammar	0.178	92	.700	ACCEPTED	10
11	Teaching Vocabulary	0.149	100	.717	ACCEPTED	7
12	Teaching Listening	0.115	100	.750	ACCEPTED	4
13	Teaching Speaking	0.115	100	.750	ACCEPTED	4
14	Teaching Reading	0.085	83	.767	ACCEPTED	3
15	Teaching Writing	0.136	100	.733	ACCEPTED	6

Notes: Conditions to be met: Triangular Fuzzy Numbers: Threshold value (d) ≤ 0.2 ; Percentage of expert consensus $\geq 75\%$. Defuzzification Process: Fuzzy score (A) $\geq \alpha$ -cut value of 0.5.

5.3 Consensus of experts on online platform and tool design

The online platform and tools design element contains items related to the development and configuration of the ML-PAD module's online learning platform. In the ML-PAD module, learners may use various mobile devices, such as laptops, smartphones, or tablet computers. The Chaoxing Learning platform was used as the primary environment for this module. Through this platform, learners can engage in study and interaction through various mobile learning devices, which include accessing learning materials shared by teachers, communicating and discussing with peers online, and completing assignments. Moreover, teachers can track and assess students' learning progress within the same platform. All these functions were mentioned in the FDM questionnaire.

The threshold value (d), the percentage of expert consensus, the defuzzification values, and the rankings of each element based on the expert consensus are shown in Table 5. Except for Item 5 (Online tests) and Item 6 (Notice), all other items reached an expert consensus exceeding 75% and a threshold value (d) below 0.2. Therefore, four items, namely Teaching plans, Resource sharing, Online discussion, and Assignments, were accepted as platform and tool design elements of the module, whereas Online tests and Notice were excluded. Among these, Resource sharing ranked first in priority.

Table 5. Experts' views on the online platform and tools

No.	Tools	Threshold Value (d)	Percentage of Expert Consensus, %	Fuzzy Score (A)	Expert Consensus	Ranking
1	Teaching plans	0.178	92	.683	ACCEPTED	3
2	Resource Sharing	0.115	100	.750	ACCEPTED	1
3	Online Discussion	0.149	100	.717	ACCEPTED	2
4	Assignments	0.178	83	.683	ACCEPTED	3
5	Online Tests	0.208	83	.683	REJECTED	–
6	Notice	0.221	75	.533	REJECTED	–

Notes: Conditions to be met: Triangular Fuzzy Numbers: Threshold value (d) ≤ 0.2 ; Percentage of expert consensus $\geq 75\%$. Defuzzification Process: Fuzzy score (A) $\geq \alpha$ -cut value of 0.5.

5.4 Expert consensus on the instructional procedure

The instructional procedure element contains items that guide the design of the ML-PAD module's teaching process. The threshold value (d), the percentage of expert consensus, the defuzzification value, and rankings of all items within this element, based on expert consensus, are shown in Table 6. The instructional procedure of the module followed the PAD Class model, which comprises three main stages: presentation, assimilation, and discussion. Mobile devices can be integrated throughout all stages of the procedure to support learning and interaction.

Items 1, 2, 3, 4, and 5 within the instructional procedure element were accepted, as they achieved an expert consensus percentage exceeding 75% and had a threshold value (d) below 0.2. Among these, Item 1 (Present key and difficult knowledge in class) and Item 4 (Discuss doubts or questions in class) both received the highest ranking, each with a defuzzification value of 0.733, followed by Item 5 (Discuss peers' teaching practices in class) with a defuzzification value of 0.717. Item 2 (Assimilate the knowledge by self-studying online resources) and Item 3 (Assimilate the knowledge by doing assignments online) recorded defuzzification values of 0.678 and 0.650, respectively. In contrast, Item 6 (Online test) was rejected, as its threshold value (0.204) exceeded 0.2.

The ranking results suggest that teachers should prioritize Items 1 and 4, which emphasize classroom presentation and discussion. These findings indicate that both presentation and discussion play equally important roles in the instructional procedure of the module.

Table 6. Experts' views on the instructional procedure elements

No.	Instructional Procedure	Threshold Value (d)	Percentage of Expert Consensus, %	Fuzzy Score (A)	Expert Consensus	Ranking
1	Present key and difficult knowledge in class	0.136	100	.733	ACCEPTED	1
2	Assimilate knowledge by self-studying online resources	0.175	92	.678	ACCEPTED	4
3	Assimilate knowledge by doing assignments online	0.153	92	.650	ACCEPTED	5
4	Discuss the doubts or questions in class	0.136	100	.733	ACCEPTED	1
5	Discuss peers' teaching practices in class	0.149	100	.717	ACCEPTED	3
6	Online test	0.204	100	.600	REJECTED	–

Notes: Conditions to be met: Triangular Fuzzy Numbers: Threshold value (d) ≤ 0.2 ; Percentage of expert consensus $\geq 75\%$. Defuzzification Process: Fuzzy score (A) $\geq \alpha$ -cut value of 0.5.

5.5 Expert consensus on the assessment strategies

The final section of the FDM questionnaire focused on the design of the assessment strategies, which were informed by the principles of formative assessment. These strategies aim not only to evaluate learning outcomes but also to support and enhance the learning process. Two assessment strategies were involved: peer assessment and e-portfolio. As presented in Table 7, both assessment strategies achieved an expert consensus level of over 75%, with a threshold value below (d) below 0.2, indicating a high level of acceptance. Furthermore, the expert ranking of these strategies suggests that peer assessment should be prioritized during implementation, given its higher importance rating.

Table 7. Experts' views on the assessment strategies

No.	Instructional Procedure	Threshold Value (d)	Percentage of Expert Consensus, %	Fuzzy Score (A)	Expert Consensus	Ranking
1	Peer assessment	0.047	92	.783	ACCEPTED	1
2	E-portfolio assessment	0.136	100	.733	ACCEPTED	2

Notes: Conditions to be met: Triangular Fuzzy Numbers: Threshold value (d) ≤ 0.2 ; Percentage of expert consensus $\geq 75\%$. Defuzzification Process: Fuzzy score (A) $\geq \alpha$ -cut value of 0.5.

5.6 The framework of the ML-PAD module

Drawing on the results of the FDM questionnaire, a framework for the ML-PAD module was developed. The flowchart of the ML-PAD module is presented in Figure 3. Throughout the three stages of the module, mobile devices are utilized to facilitate continuous and flexible learning.

In the presentation stage, teachers deliver face-to-face instruction focusing on key and difficult points while simultaneously uploading related instructional materials, such as teaching slides, to the Chaoxing Learning platform. Students can subsequently review the materials at their own pace after class.

The second stage, assimilation, is entirely conducted via mobile devices. During this phase, students independently study and review the learning materials related to the technological, pedagogical, and CK of EFL instruction shared by the teacher. They are asked to internalize the key points of each lesson, design corresponding lesson plans, and prepare for the simulated teaching practice in the next session. In addition, students are required to use mobile devices to complete online assignments. These assignments involve organizing the knowledge learned in the current lesson, the teaching resources they have collected, and the related digital teaching materials shared by the instructor, then uploading them to their personal e-portfolios to build an individual digital teaching resource repository. Through this process, students can better internalize and comprehend what they have learned.

The final stage, discussion, focuses on interactive and reflective learning. Students conduct simulated teaching practice in class and engage in both in-class and online discussions to exchange feedback and deepen their understanding of effective EFL instructional practices (see Figure 3).

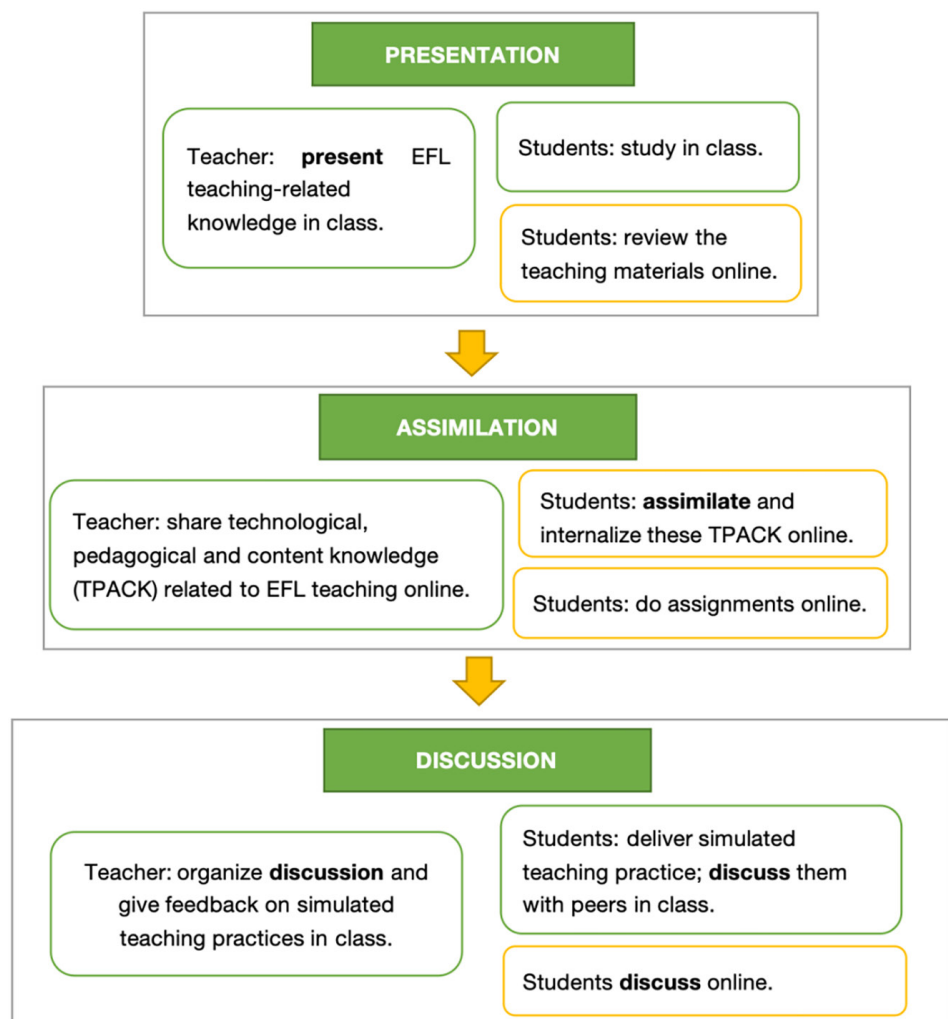


Fig. 3. The flowchart of the ML-PAD module

6 DISCUSSION

In the present study, five constructs were established for the design of the ML-PAD module based on the PAD Class model using the FDM. These constructs were identified through semi-structured interviews conducted with four experts initially, who recommended adopting Tyler's [42] instructional design framework as the theoretical foundation to guide the module design. Tyler [42] conceptualized the instructional design process through a "why-what-how-how well" framework. "Why" defines the educational purposes of the module, which form the foundation of the pedagogical framework. As the initial step, clarifying the objectives ensures that all the following elements are aligned. "What" focuses on the learning contents, forming the core of the module design. "How" refers to the methods of delivering learning content and achieving the intended learning objectives. In this study, the "How" component is further defined through two key elements: the instructional procedure and the design of the mobile-assisted device. Finally, the "How well" component focuses on evaluation criteria for examining learning processes and outcomes. Establishing clear evaluation criteria is critical because it helps determine the extent to which the instructional objectives are addressed. Following the expert review, twelve experts reached a consensus on five constructs comprising 33 elements. The accepted elements represent expert-validated design intentions regarding the design and structure of the ML-PAD module and should not be interpreted as evidence of actual improvement in pre-service teachers' ICT teaching competency. The proposed components of the module will be discussed in the following section.

Experts agreed that the objectives of pedagogy courses in EFL teacher education programs should focus on two key areas: PK and ICT teaching competency. The objectives concerning PK include basic theories, principles, methods, and strategies of EFL teaching and learning, which directly echo the PK dimension of the TPACK framework [41]. Simultaneously, the second instructional objective addresses skills related to instructional design, teaching courseware development, the integration of ICT into EFL teaching and learning, and the mastery of ICT in the EFL teaching context. These skills align with the core components of ICT teaching competency, which comprise three key parts: technology literacy, the ability to use ICT to support learning, and the ability to use ICT to support teaching [5]. Notably, these skills demonstrate a high degree of structural alignment with UNESCO's ICT Competency Framework for Teachers [2]. For instance, the emphasis on "mastery of ICT in EFL contexts" reflects what UNESCO defines as the "knowledge deepening" stage, where technology is integrated to support subject-specific learning outcomes. This alignment suggests the potential transferability of the ML-PAD module to teacher education contexts with similar pedagogical and technological conditions.

In terms of content design, the experts reached a consensus on adopting an integrated structural logic grounded in the TPACK framework [41]. In the ML-PAD module, this integration is reflected in the systematic connection between PK (e.g., EFL teaching methods, lesson planning, and classroom management), CK (e.g., pronunciation, grammar, and vocabulary-based instruction), and Technological Knowledge (TK) (e.g., instructional courseware development and the use of ICT in EFL teaching). Such an approach resonates with the view that digital competence cannot be developed through technical training alone but requires a close relationship among subject matter, pedagogy, and technology use [5], [43]–[45]. Building on this perspective, this design aligns with the findings of [43] and [44], who advocate for the adoption of TPACK as an essential framework for preparing pre-service teachers within teacher education programs.

Regarding the design of the online platform and tools, the Chaoxing Learning platform was adopted as the learning management platform to support ICT teaching competency. Within the ML-PAD module, learners access the platform through various mobile devices, including smartphones, laptops, and tablets. Based on expert consensus, four specific functions were utilized: resource sharing, online discussion, teaching plans, and assignments. The selection of these functions differs from the seven-function model identified in [17] for a Production-Oriented Approach (POA) interpreting module; while [17] emphasizes individual output and data analysis, the ML-PAD module prioritizes structural scaffolding and collaborative internalization. This focus aligns with the PAD Class model's core logic of transitioning from instructor-led presentation to learner-centered assimilation. Furthermore, the experts noted that these tools are fundamental across mainstream Learning Management Systems (LMS) such as Moodle and Canvas. This indicates that the ML-PAD module relies on widely accessible instructional features rather than platform-specific technologies, suggesting its potential for adaptation to other training programs.

When it comes to the procedure design, experts achieved a high level of consensus on the three-phase implementation of the ML-PAD module, including presentation, assimilation, and discussion. In the Presentation stage, Zhang's [20] principles suggest that instead of covering every detail, instructors should focus on explaining the logical framework and the significance of key concepts to stimulate students' learning initiative and interest. The FDM results showed that experts strongly supported the idea of instructors focusing on difficult and important points. This approach facilitates a concise explanation from the teacher and is intended to provide learners with conceptual guidance and preparatory support for the subsequent phases. Regarding the Assimilation stage, the FDM results indicate a strong preference for two main approaches: online self-study and assignment completion. By using mobile devices, learners can access subject-specific digital resources at their own pace [21], including EFL instructional videos, exemplary lesson plans, educational policies, and MOOCs about ICT in EFL teaching. Furthermore, experts agreed that assignments are necessary supplements to self-study, helping to consolidate knowledge and allowing students to check their own learning progress. This phase serves as a crucial bridge, giving students enough time to absorb information before engaging in the subsequent interaction. During the Discussion stage, experts agreed on a hybrid approach that combines both online and offline interaction. This stage focuses on addressing difficulties identified during the assimilation stage and issues arising from peer-simulated teaching. Learners are presented with opportunities for active interaction and immediate feedback through face-to-face discussion; furthermore, introverted or hesitant learners are empowered to express ideas via their mobile devices. This combined approach is intended to support learner engagement and encourage active participation during classroom interaction. Compared to the traditional Flipped Classroom, the ML-PAD module offers a more structured scaffold. Sharom and Kew [47] reported that flipped models may lead to fragmented understanding when students fail to internalize learning materials prior to class, noting that only 42% of studies verified pre-class comprehension. The ML-PAD module was designed to address this limitation through the Presentation and Assimilation stages, which are intended to provide learners with a foundational basis for subsequent peer interaction. This structured transition ensures that discussions are grounded in deep reflection, thereby creating conditions that may support deeper knowledge construction.

The final construct is the assessment strategy design. The experts agreed on using peer assessment and e-portfolios to evaluate learning outcomes. The expert consensus on adopting peer assessment aligns with findings by [47] and [48], who demonstrated that peer feedback enhances learners' academic performance, critical thinking, and communication skills. With regard to e-portfolio assessment, it is used to document learners' learning progress, reflections, and digital teaching practices throughout the ML-PAD module, serving both formative and summative evaluation approaches. This assessment design is supported by previous studies. Lavonen et al. [49] suggested that assessing ICT teaching ability requires continuous, process-oriented, and dynamic data sources rather than isolated skill training. Şahin [50] and O'Reilly [51] further found that constructivist, project-based tasks provide a more meaningful alternative to traditional testing, as they link theory with practice and promote motivation for ICT use.

The high level of consensus among the twelve experts suggests that the ML-PAD module has strong structural coherence and content appropriateness. While the expert panel provided localized insights, the FDM results indicate that the module is characterized more by pedagogical alignment rather than specific technical features. By integrating the PAD Class model with mobile-assisted learning, the design is theoretically positioned to bridge instructor-led scaffolding and learner-centered internalization. The structured approach therefore provides a theoretically grounded framework designed to support ICT teaching competency development among pre-service EFL teachers. It should be noted that the expert panel in this study was relatively small and limited to EFL and educational technology experts from China, which may limit the broader transferability of the findings. Although four experts had experience serving as reviewers for international peer-reviewed journals, the panel remained geographically and contextually concentrated in southern China. Therefore, the reported consensus should be interpreted as context-specific rather than as evidence of international validation.

Furthermore, the ML-PAD module also echoes the recent discussion on digital literacy in the Global South [52]. Nualprasert et al. [52] emphasized that integrating technology in teacher education is not just about using tools but also about combining pedagogy, technology, and CK within the TPACK framework. Consistent with this perspective, the ML-PAD module prioritizes fundamental LMS functions, such as discussion and resource sharing, rather than advanced technological features. This design orientation is also consistent with Drolia et al. [53], who highlighted the importance of accessibility and contextual appropriateness in mobile learning design, particularly in resource-constrained educational settings. Accordingly, the ML-PAD module adopts a pedagogically driven and context-sensitive approach to ICT integration by utilizing widely available mobile devices and learning activities that support learner engagement during the assimilation and discussion phases.

Although this study does not claim broad international applicability, certain aspects of the ML-PAD module may offer useful references for similar teacher education contexts. In particular, the PAD instructional structure, collaborative learning design, and assessment framework may have potential transferability with appropriate contextual adaptation. However, elements such as digital platform selection, institutional support conditions, curriculum requirements, and learners' access to mobile technologies remain highly context-dependent and should be adjusted according to local educational environments. Therefore, the ML-PAD module may provide useful design references for similar teacher education settings, while future

empirical studies are needed to examine its implementation across different educational contexts.

7 CONCLUSION

This study presents the findings of an FDM in designing and validating the components and constructs of a mobile learning-based PAD Class module (ML-PAD) to support ICT teaching competency development among pre-service EFL teachers. The FDM findings indicate that the twelve experts reached consensus on five constructs and their corresponding elements, supporting the pedagogical coherence and structural design of the ML-PAD module within EFL teacher education courses.

This study has made several contributions to educational research. First, the ML-PAD module provides a structured and practice-oriented instructional framework designed to support ICT teaching competency development in pre-service EFL teacher education. By clarifying instructional procedures and task design, the module contributes to ongoing discussions on teacher education reform and the integration of technology-enhanced pedagogy. Second, this study advances the development and application of the PAD Class model by integrating mobile learning into the traditional framework to create opportunities for student-centered, technology-enhanced, and collaborative learning. Unlike conventional flipped classrooms that often suffer from a disconnected pre-class phase [46], the ML-PAD module introduces a structured Assimilation stage. Third, the study contributes to the application of the FDM. Through the systematic application of FDM to develop and validate a teaching design integrating mobile learning, the PAD Class model, and ICT teaching competency, expert consensus was achieved on the teaching objectives, content, procedures, mobile devices, and assessment strategies, highlighting the potential of FDM in instructional design research. Finally, the study contributes to the integration of theory and practice. The ML-PAD module integrates the PAD Class model, the TPACK framework, mobile learning, and FDM, offering conceptual and instructional design implications for teacher professional development initiatives, ICT-based classroom instruction, and mobile learning research. Consequently, these findings provide useful theoretical and practical references for ICT-integrated EFL teacher education within similar educational contexts.

Regarding the limitations of the study, first, the expert panel was relatively small and consisted primarily of experts from China, which may limit the generalizability of the findings to other educational contexts. The relatively homogeneous professional and regional backgrounds of the participating experts may also have contributed to the rapid convergence of opinions observed during the single-round FDM process. Although the ML-PAD module is grounded in international frameworks such as TPACK and UNESCO's ICT Competency Framework for Teachers, its applicability beyond the current context requires further empirical examination. The transferability of the module is primarily reflected in its instructional structure, pedagogical design principles, and assessment framework, whereas platform-specific implementation may require contextual adaptation according to local technological and institutional conditions. Future research could involve more geographically diverse expert panels and empirical investigations in different educational settings to further examine the contextual adaptability of the ML-PAD module. Second, the study focused exclusively on pre-service EFL teachers. While this focus allowed for a more in-depth examination of ICT teaching competency in this context, it limits the generalization of

the findings to pre-service teachers from other subject areas. Third, although a single round of FDM was adopted due to the high level of consensus achieved, which is considered methodologically acceptable in similar studies, it is acknowledged that additional rounds could further strengthen the robustness of the findings. Future studies could expand the participant pool to include pre-service teachers from other disciplines and conduct multi-round FDM analyses to further refine the module design.

The ML-PAD module offers a flexible instructional framework for integrating mobile learning into EFL teacher education and blended learning environments. At the same time, its implementation may require adaptation according to local technological resources, institutional conditions, and curriculum requirements while maintaining the pedagogical logic of the PAD structure. Future research could conduct quasi-experiments to assess the instructional effects of the ML-PAD module. Action research may also be carried out to explore its implementation process in authentic classroom contexts. In addition, surveys and interviews can be used to collect user feedback, while multi-dimensional assessment can be employed to evaluate its instructional performance in practice more comprehensively. Overall, the ML-PAD module provides a theoretically grounded and context-sensitive framework for future instructional design and empirical evaluation of its implementation within EFL teacher education.

8 ETHICS STATEMENT

This study was conducted in accordance with the ethical guidelines for research involving human participants. The research protocol was reviewed and approved by the Institutional Review Board of Science and Technology College Gannan Normal University (Approval Date: 2025-08-21). All the twelve participating experts were fully informed about the purpose, procedures, and voluntary nature of the study prior to their involvement. Written informed consent was obtained from each participant before completing the questionnaires and participating in the interviews. Interviews were audio-recorded with permission and transcribed for analysis. To protect participants' privacy, all data were anonymized and used solely for academic research purposes.

9 DECLARATIONS

The authors certify that this paper is original and has not been previously published. The manuscript is not currently under consideration for publication elsewhere.

The authors used ChatGPT only for language polishing and grammar refinement. All intellectual content, analysis, and interpretations were developed and verified by the authors, who take full responsibility for the manuscript.

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