

Empowering Educators to Develop Augmented Reality Applications by Integrating Computational Thinking and Experiential Learning

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Abstract—Augmented reality (AR) promises rich, immersive experiences in learning, yet many educators lack the technical expertise to develop AR content independently. Existing authoring environments often emphasise functionality over instructional design, leaving educators reliant on pre-built resources that seldom match their learning goals. This study proposes EduCATE-AR, a template-based authoring model that integrates Experiential Learning (EL) and Computational Thinking (CT) to embed pedagogies directly into a modular-based authoring approach. Using a three-phase design science research approach, pedagogical principles were mapped onto AR authoring workflows to develop the model. A template-based editing environment was then constructed based on these mappings, and its use was evaluated through a mixed-methods study involving a focus group with educators. Quantitative results based on the Technology Acceptance Model (TAM) indicated strong perceived usefulness and intention to use, particularly among educators without prior AR development experience. Qualitative findings further highlighted the model's value in reducing technical barriers and supporting pedagogical structuring, while also revealing the need for improved extensibility and subject-specific flexibility. Collectively, the proposed model is a valuable addition to AR instructional design by empowering educators as content creators to develop pedagogically aligned AR applications with greater autonomy.

Keywords—Augmented reality; content creation; instructional design; template-based authoring; experiential learning; computational thinking

I. INTRODUCTION

With the advancement of technologies, digital-native learners are expecting visually rich and interactive educational content, pushing educators to adopt more engaging instructional strategies. Among the possible technologies, Augmented Reality (AR) particularly stands out for its ability to overlay real-world environments with dynamic digital content, offering immersion in the learning experiences [1-4] to improve motivation and interests [5-9]. While AR is often accessed through mobile devices and marker-based tracking [10, 11], its adoption tends to prioritise engagement. Learners may initially be engaged; however, feature-driven applications can result in superficial engagement, lacking the depth required for sustained knowledge acquisition [12]. Hence, a critical challenge persists:

how can AR experiences be designed to achieve not only engagement but also pedagogically meaningful learning?

Developing AR applications in education is not without its limitations. Studies in AR authoring often emphasise technical capabilities in interactivity but pay less attention to pedagogical structuring, which places usability barriers and limits educators' involvement in shaping meaningful AR learning experiences [13-15]. The disconnection of pedagogical relevance in AR content is a concern echoed in recent reviews of AR adoption in education [16]. Although approaches like inquiry-based and situated learning have been constantly explored within AR [17-19], there is limited integration of structured pedagogies like Experiential Learning (EL) and Computational Thinking (CT) in providing support for AR design that emphasises both reflective thinking and systematic problem-solving.

Integrating these structured pedagogies can provide a foundation for enhancing the educational impact of AR [20] by moving beyond surface-level engagement toward deeper learning outcomes. EL supports reflective learning through a cycle of experience, reflection, conceptualisation, and application [21-23], which aligns naturally with AR's immersive potential. CT, on the other hand, fosters essential cognitive skills through processes such as pattern recognition, decomposition, abstraction, and algorithmic reasoning [24-26], providing a valuable approach for designing logic-driven AR learning tasks. Although EL and CT have been applied separately in AR learning environments [24, 27, 28], their combined potential within a unified AR content creation framework remains largely unexplored.

To address these challenges, this study proposes a template-based authoring model designed for educators with limited technical expertise. The model integrates EL and CT principles directly into the AR content creation workflow, embedding pedagogical structure into modular templates. The study employed a focus group methodology to evaluate the model's pedagogical alignment and usability, gathering feedback through open-ended reflections and Technology Acceptance Model (TAM)-based questions. Specifically, the research investigates: 1) how EL and CT can be systematically mapped into an AR authoring model (RQ1), 2) how prior AR development experience influences educators' perceptions of

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the model (RQ2), and 3) which features are most valued, and what refinements are considered necessary for effective adoption (RQ3).

The remaining sections of this study have been structured in the following manner. Section II provides a review of related work on AR applications in education and their pedagogical underpinnings. Section III outlines the research design, introduces the proposed template, and defines participant recruitment, focus group procedures, and data analysis approach. Sections IV and V present the findings and discussion from the focus group discussions, examining educators' reflections on pedagogical needs, perceived challenges, and opportunities for AR content creation. Finally, Section VI provides the conclusion, which shows the study's limitations and directions for future research.

II. RELATED WORKS

The potential of AR to enhance learners' engagement and encourage positive learning attitudes has received considerable attention in the field of education. Even though current studies are largely centered on demonstrating AR's advantages for learners, a growing body of literature is starting to shift towards the involvement of educators as primary creators of AR content. Despite this shift, much of the existing literature leans towards the technical capability of authoring tools, or their usability from a technical perspective [13, 29], omitting clear guidance on aligning AR activities with learning objectives.

A. Authoring Environment for AR Content Creation

AR authoring environments vary widely in both their level of technical abstraction and the extent of pedagogical support

they offer, as depicted in Table I. Three recurring patterns emerge from the literature. Firstly, based on authoring style, visual editing environments help in lowering the entry barrier for educators [24, 30, 31]. Template-based editing can also accelerate content reuse [32, 33], yet in practice, most of these tools often produce static overlays with limited adaptability. As for pedagogy integration, it is explicitly seen in ExposAR [24], where learners are engaging in CT concepts during AR activities. However, none of the reviewed authoring environments systematically integrates the EL cycle to guide lesson sequencing. Moreover, since engagement with AR content is deemed important [34, 35], many authoring tools still offer restricted interactivity, missing opportunities for real-time manipulation and learner-driven exploration [36-38].

Gaps in AR authoring environments become more apparent when they are seen to reduce programming load on educators, but are mostly still privileging technical usability over a structured, theory-driven approach to AR design. For instance, Paper Trail [37] and WebArt [36] offer immersive experiences with tangible artefacts and web-based capabilities, respectively, but their main focus remains on interaction mechanics and visual augmentation, rather than on embedding a pedagogical framework into the flow of activities. Therefore, this investigation addresses the need to provide educators with a low-effort, high-guidance AR content creation process that integrates EL and CT while preserving the learner-driven interactivity that mobile AR affords. The EduCATE-AR model addresses this shortfall by embedding pedagogical concepts drawn from EL and CT directly into each authoring step.

TABLE I. SPECIFICATIONS OF EXISTING AR AUTHORING TOOLS

Ref.		[32]	[39]	[40]	[33]	[36]	[31]	[41]	[30]	[38]	[24]	[37]
Authoring Style	Template Editing	✓	✓	✓	✓	✓						
	Visual Editing						✓	✓	✓	✓	✓	✓
Pedagogy	Situated Learning	✓										
	Learning- while-making									✓		
	Distance Learning		✓					✓				
	Computational Thinking										✓	
Interactivity	Static		✓	✓	✓			✓	✓			
	Dynamic	✓				✓	✓			✓	✓	✓

B. Integration of Experiential Learning and Computational Thinking in AR Content

EL involves a continuous four-stage cycle that facilitates knowledge construction through experience and application [42]. AR can strengthen this cycle by providing immersive environments, real-time feedback, and interactive content [21, 43, 44], hence connecting hands-on activities with cognitive learning [45]. CT, by contrast, is a series of cognitive processes that uses approaches comparable to those applied in computing [25, 26, 46]. When applied within AR, CT enables structured problem-solving through tasks such as programming sequences, as demonstrated in the ARQuest game [47]. Together, EL and CT provide a strong pedagogical foundation for AR content,

where EL fosters experiential and reflective learning, while CT instills logic and structured reasoning. Their integration transforms AR into a meaningful instructional medium that supports both cognitive growth and hands-on engagement. As noted by Ramli et al. [48], effective AR pedagogy must address the what, why, and how of learning. Hence, the first two are outlined in Table II, whereas the how is clarified through the EL-CT alignment presented in this study.

Researchers have noted persistent inconsistencies between technological capabilities and instructional objectives, resulting in AR applications that may capture students' attention but fall short in promoting deep learning [12, 16, 49]. While EL and CT have demonstrated value in AR, they are rarely embedded within authoring tools, creating a technological-pedagogical

gap that can limit the educational usefulness of AR applications among educators [12]. Moreover, studies have shown that AR adoption is shaped by factors beyond technical features. The MARAM model by Koutromanos et al. [50] extends TAM to incorporate dimensions such as perceived usefulness, ease of use, facilitating conditions, and self-efficacy, highlighting their influence on AR adoption by educators.

TABLE II. THEORETICAL GROUNDING OF EXPERIENTIAL LEARNING AND COMPUTATIONAL THINKING IN AR

Approach	Explanation		Ref.
Experiential Learning	What	A learning theory that promotes active knowledge construction through immersive and interactive AR activities, allowing learners to engage directly with simulated environments.	[51, 52]
	Why	Enhance motivation and engagement in AR by enabling learners to explore digital representations of real-world phenomena, make personal discoveries, and reflect on their experiences within the AR space.	[28, 42, 43]
Computational Thinking	What	A cognitive approach to solving problems in digital contexts.	[25, 26, 46, 53]
	Why	Fosters critical thinking skills and 21 st -century competencies through structured, logic-based learning in interactive environments.	[25, 54]

Hence, by integrating EL and CT into a single template-based design, this study responds directly to calls for pedagogically aligned AR design while preserving ease of use for educators. It underpins the investigation of how the authoring model supports pedagogical mapping, its acceptance across varying levels of background expertise, and how users identify helpful features and areas for improvement, ensuring that the model meets educators' needs and further advances the AR's potential for adoption.

III. METHODOLOGY

The study followed a three-phase design science research sequence that progresses from solution design to artefact construction and empirical evaluation, as illustrated in Fig. 1. Phase 1 encompasses the authoring model that maps EL phases with complementary CT skills to mobile AR interactions, thereby addressing RQ1. Phase 2 translated the model design into the form of a working authoring template, demonstrating the feasibility of implementing the EL-CT alignments for AR content creation. Phase 3 gathered educators' perceptions through a focus-group study, generating evidence for RQ2 and RQ3. Consistent with design science research, in which empirical evaluation may take the form of satisfaction and

perception-based feedback [55]. The study's evaluation was scoped to perceived usefulness and usability prior to performing any classroom-based effectiveness assessment. This practice ensures that each research question is examined at the stage most suited to its focus and that later insights remain anchored in the established conceptual groundwork.

A. Alignment of Experiential Learning and Computational Thinking in AR Content

The EduCATE-AR model is grounded in EL, comprising four phases, which are Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualisation (AC), and Active Experimentation (AE). Each phase is paired with a CT practice and a cognitive task: 1) Pattern Recognition (PR) and Identifying for CE, 2) Abstraction (AB) and Interpreting for RO, 3) Decomposition and Relating for AC, and (4) Algorithmic Thinking (AL) and Sequencing for AE, as presented in Fig. 2. Table III details how each module's AR interaction supports its cognitive task, where the complexity of that cognition is shaped by the learning activity's design. For instance, at CE, scale-and-rotate can range from recognising a single feature to a more complex spatial analysis across various viewpoints. Tap-to-reveal in RO enables the retrieval of a single contextual annotation, extending to drawing connections across several related details. In AC, scale-and-rotate similarly supports viewing an individual component in isolation, though it can equally demand reasoning about how multiple components function together. Drag-and-drop at AE is capable of simple recall through reordering pre-labelled steps, up to inferring the correct sequence through procedural reasoning.

TABLE III. AR CONTENT DESIGN BASED ON THE LEARNING MODULES

Cognitive-based Module	AR Interaction	Learning Objective in AR
Identifying	Two-finger (scale-and-rotate)	LO1: Learners observe and explore virtual objects in the AR environment to identify recurring features and build initial familiarity.
Interpreting	One-finger (tap-to-reveal)	LO2: Learners extract meaning from their prior observations by accessing contextual annotations on virtual objects that highlight important features.
Relating	Two-finger (scale-and-rotate)	LO3: Learners break down AR content into individual components for inspection to understand their functions and relationships within the overall concept.
Sequencing	One-finger (drag-and-drop)	LO4: Learners test their ordered actions in a new scenario and observe the outcome.

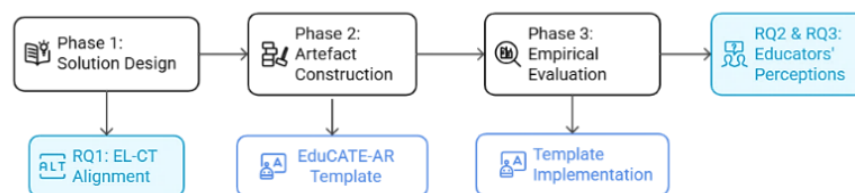


Fig. 1. Research design of the study.

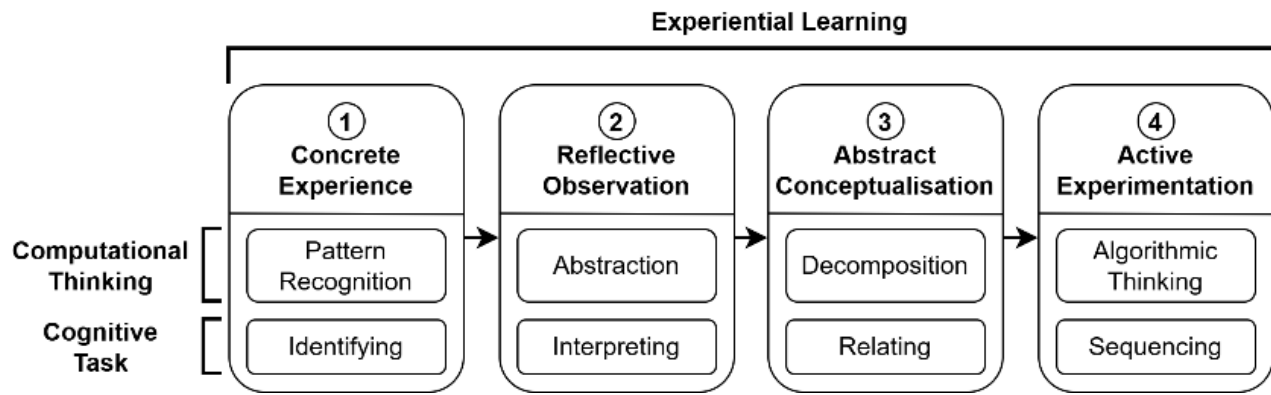


Fig. 2. Experiential learning and computational thinking mapping with cognitive task.

B. Design of the Proposed Authoring Model

As depicted in Fig. 3, the EduCATE-AR model integrates EL phases, CT practices, cognitive tasks, and AR interactions into a template-based authoring flow, addressing RQ1 by demonstrating how these elements can be systematically embedded in content creation. The template layer contains four sequential modules, one per EL phase (CE→RO→AC→AE), each pairing its CT practice, cognitive task, and AR interaction as detailed in Table III. Educators assemble lessons by selecting these modules and configuring their content, while the template handles the technical implementation of each AR interaction.

This template design is realised in Unity. Each of the four modules is packaged as a prefab, which is a ready-made object bundle containing its own scripts, components, and behaviours, as shown in Fig. 4, so it can be placed into a scene and used directly, without being rebuilt each time. Each prefab is linked to a physical marker, a printed image that the AR camera can recognise. When the camera detects a marker, Vuforia identifies it and triggers Unity to load the matching prefab, rendering its AR content at that location in the real-world scene. Once the content appears, Leap Touch captures the learner's gesture, such as rotating, tapping, or dragging, to support interaction with the AR content.

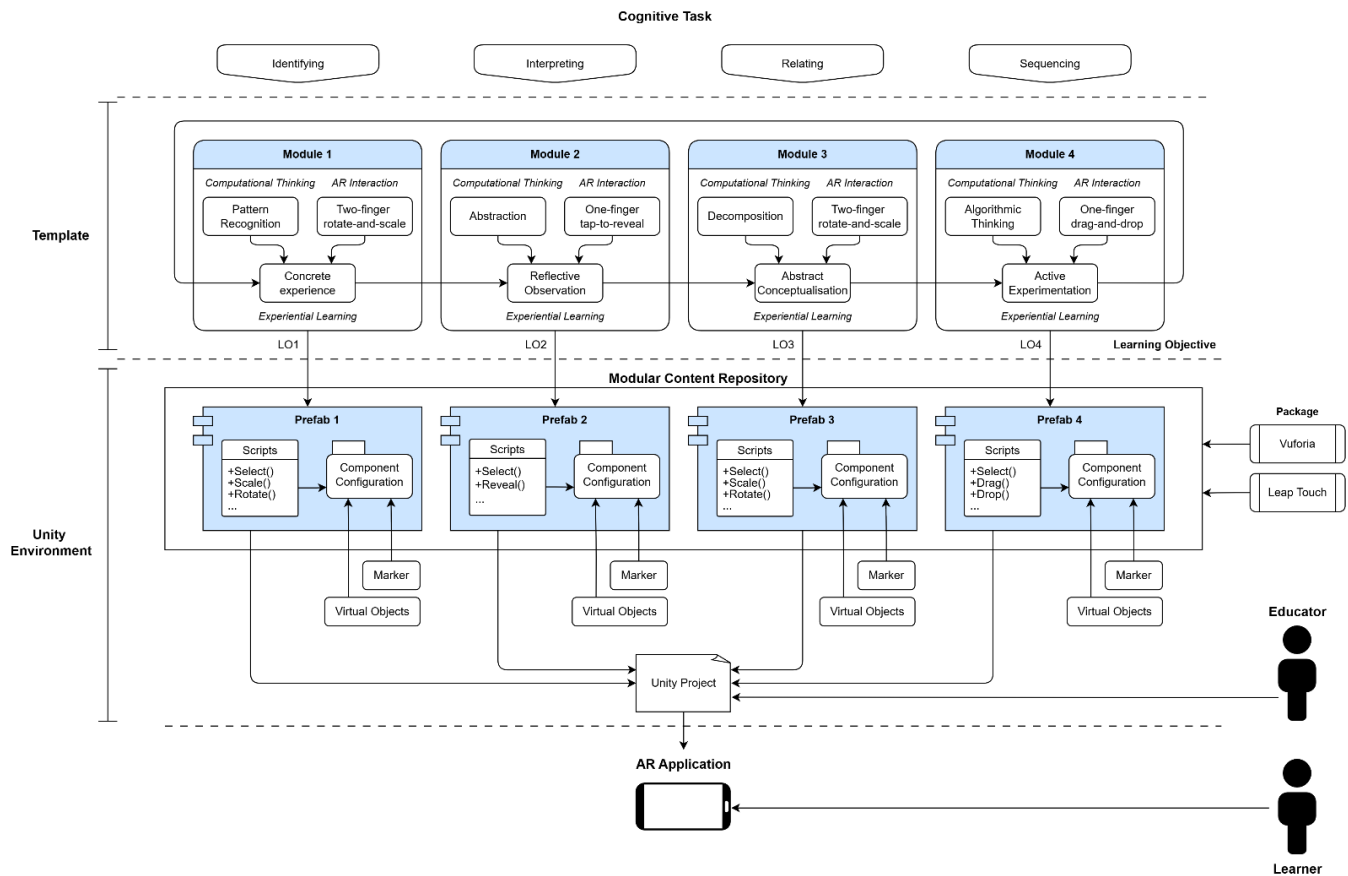


Fig. 3. EduCATE-AR model for template-based AR content creation.

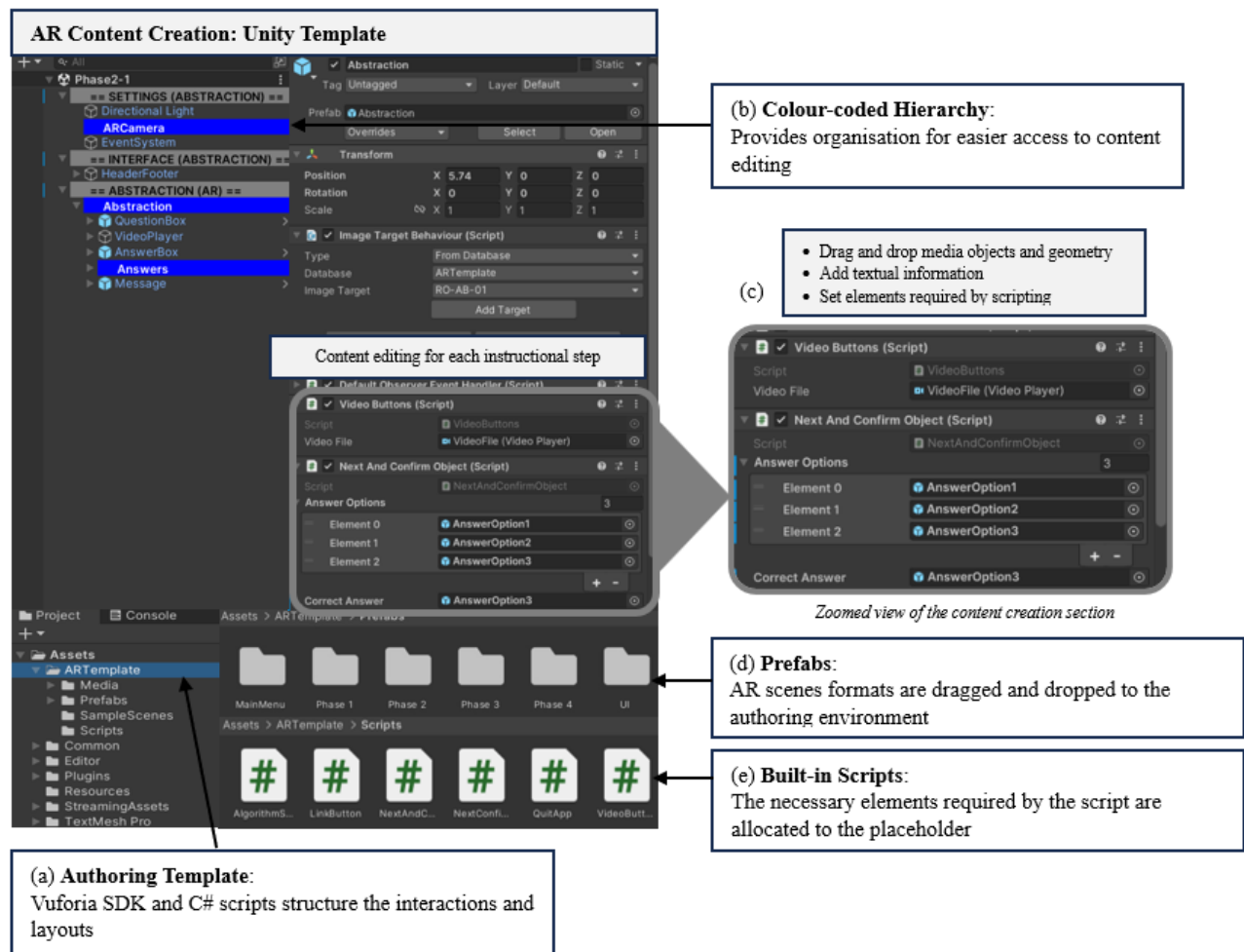


Fig. 4. EduCATE-AR template for educational AR content creation.

Each module in the model is realised as one of four prefabs, matched to its EL phase, CT practice, and cognitive task. Prefab 1 (CE-PR, Identifying) enables open exploration, where learners scale and rotate a virtual object from different angles to spot recurring visual features. Prefab 2 (RO-AB, Interpreting) supports sense-making from those observations, where learners tap to reveal contextual annotations that explain what they are looking at. Prefab 3 (AC-DC, Relating) supports component-level inspection, allowing learners to scale and rotate individual parts of a more complex object to see how each part relates to the whole. Prefab 4 (AE-AL, Sequencing) supports applied problem-solving by providing learners with drag-and-drop elements to be placed in the correct order for testing their understanding in a new scenario. Together, this prefab structure keeps the EL-CT sequence embedded in the authoring process rather than in code, so educators build lessons by selecting and configuring these prefabs instead of programming them directly.

C. Experimental Design and Implementation

This study adopted a focus group evaluation of the EduCATE-AR template. Educators' experiences were examined using TAM [56] and thematic analysis of open-ended reflections, providing a comprehensive view of usability, pedagogical fit, and perceived instructional value [20].

TABLE IV. DISTRIBUTION OF EDUCATORS' DEMOGRAPHIC PROFILE

Demographic (N = 18)	Category	Frequency	Percentage (%)
Gender	Male	5	27.78
	Female	13	72.22
Age	30 - 34	8	44.44
	35 - 39	7	38.89
	40 - 44	1	5.56
	45 - 49	2	11.11
Teaching Subject / Discipline	Computing	11	61.11
	Science	2	11.11
	Language	3	16.67
	Business	2	11.11
AR Development	Experienced	5	27.78
Experience	Non-experienced	13	72.22

1) *Participants*: Eighteen educators, consisting of school teachers and university lecturers, participated voluntarily and were selected through an open invitation. All participants provided informed consent and were anonymised using unique

identifiers. As shown in Table IV, most participants were female (72.22%) and aged between 30 and 39 (83.33%). The majority taught Computing (61.11%), but most did not have prior AR development experience (72.22%). Based on their profiles, this group was able to offer perspectives from both technical and non-technical backgrounds. A sample size of 18 educators is appropriate for a focus group-based study, as thematic insights are commonly achieved with approximately 12 to 18 participants [57, 58] and prior studies employing similar designs in educational technology contexts have used similar or smaller samples [59, 60].

2) *Procedure*: A workshop was conducted to introduce participants to key AR concepts, CT and EL pedagogies, and essential Unity workflows. This was followed by hands-on training using the EduCATE-AR template (Fig. 5), where educators created an AR application focused on geometric shapes. The session was facilitated to help them through content development, including sequencing AR modules across EL stages and embedding the corresponding CT practices, so each authoring step targeted a clear learning objective.



Fig. 5. Educators using the EduCATE-AR template during AR content creation.

3) *Measurements and variables*: A mixed-methods approach was employed to evaluate how well the EduCATE-AR template aligns with educators' pedagogical and technical needs. Quantitative data were collected using an 11-item TAM-based questionnaire measuring Perceived Usefulness (PU), Perceived Ease of Use (PEU), and Intention to Use (ITU) on a 7-point Likert scale. Qualitative data were also gathered through two open-ended questions capturing participants' reflections and suggestions. Thematic analysis was conducted and triangulated with TAM findings to identify converging insights. Additionally, prior AR development experience was examined as a moderating factor influencing perceptions.

IV. RESULTS

This section presents the quantitative and qualitative findings from the focus-group evaluation, covering educators' TAM-based perceptions and the thematic patterns identified in their reflections.

A. Educators' Perceptions Based on Technology Acceptance Model

Descriptive statistics were calculated for each TAM construct to evaluate participants' overall perceptions of the EduCATE-AR template. Internal reliability for all constructs was robust, with Cronbach's alpha values exceeding the recommended threshold: PU ($\alpha = 0.824$), PEU ($\alpha = 0.976$), and ITU ($\alpha = 0.925$), confirming the reliability of the instrument in capturing educators' perceptions towards the template. As shown in Table V, PU ($M = 6.694$, $SD = 0.425$) emerged as the highest-rated dimension, indicating strong educators' agreement regarding the template's relevance to pedagogical goals and facilitating the development of interactive AR content. This was followed by ITU ($M = 6.333$, $SD = 0.825$), suggesting that educators showed willingness to adopt the template in future practice. PEU received a slightly lower mean score ($M = 6.097$, $SD = 1.473$), reflecting varied individual experiences during template usage. This signals potential challenges in conceptual clarity for some educators, particularly those without prior exposure to Unity or AR development.

TABLE V. MEAN (M), STANDARD DEVIATION (SD) AND CRONBACH'S ALPHA (A) FOR ITEMS IN TAM CONSTRUCTS

Item	Question	M	SD	α
Perceived Usefulness		6.694	0.425	0.824
PU1	The template helps me create AR applications that meet my teaching goals.	6.611	0.502	
PU2	The template makes it easier to integrate pedagogies in my AR applications.	6.778	0.428	
PU3	The template improves the lesson quality of my AR applications.	6.611	0.608	
PU4	The template lets me create AR applications with interactive elements.	6.778	0.548	
Perceived Ease of Use		6.097	1.473	0.976
PEU1	Learning how to use the template is easy.	6.167	1.505	
PEU2	The template makes it easy to create AR applications with minimal effort.	6.278	1.447	
PEU3	The steps for building an AR lesson with the template are simple.	5.833	1.618	
PEU4	The interface and structure of the template are understandable.	6.111	1.530	
Intention to Use		6.333	0.825	0.925
ITU1	I am interested in using the template for future AR applications.	6.389	0.778	
ITU2	Given the opportunity, I will use the template in my teaching practice.	6.278	0.826	
ITU3	I will use the template to integrate pedagogies in my future AR applications.	6.333	1.029	

To evaluate whether perceptions differed based on educators' prior expertise in AR content creation, a Mann-Whitney U test was conducted for each TAM construct. Prior to group comparison, the Shapiro-Wilk test was used to assess

normality separately within each experience subgroup. As presented in Table VI, all three constructs showed significant deviation from normality within the non-experienced subgroup, while the experienced subgroup did not. Given the non-normality observed in the larger subgroup, non-parametric analysis was adopted for both comparisons.

TABLE VI. SHAPIRO-WILK TEST FOR NORMALITY OF TAM CONSTRUCTS

Variables	Group	Shapiro-Wilk		
		<i>W</i>	<i>df</i>	<i>p</i>
Perceived usefulness	Non-experienced	0.513	13	<.001
(PU)	Experienced	0.902	5	0.421
Perceived ease of use	Non-experienced	0.689	13	<.001
(PEU)	Experienced	0.894	5	0.377
Intention to use	Non-experienced	0.658	13	<.001
(ITU)	Experienced	0.828	5	0.135

TABLE VII. MANN-WHITNEY U TEST COMPARING TAM SCORES BASED ON EXPERTISE IN AR DEVELOPMENT

Variables	Expertise in AR	<i>N</i>	Mean Rank	Total Rank	<i>U</i>	<i>p</i>	<i>r</i>
Perceived usefulness (PU)	Non-experienced	13	11.46	149.00	7.000	0.010	0.785
	Experienced	5	4.40	22.00			
Perceived ease of use (PEU)	Non-experienced	13	9.19	119.50	28.500	0.703	0.123
	Experienced	5	10.30	51.50			
Intention to use (ITU)	Non-experienced	13	11.04	143.50	12.500	0.046	0.615
	Experienced	5	5.50	27.50			

The application of the Mann-Whitney U test ensured the robustness of inferential comparisons and supported the integrity of the conclusions drawn about educators' differing levels of acceptance. Table VII reports that non-experienced participants give significantly higher scores for PU ($U = 7.000$, $p = 0.010$) and ITU ($U = 12.500$, $p = 0.046$) compared to experienced participants, while PEU did not significantly differ between groups ($U = 28.500$, $p = 0.703$), indicating a shared perception of usability irrespective of prior exposure to AR development. Given the smaller experienced subgroup ($n=5$), rank-biserial effect sizes were also computed for each comparison. ITU ($r=0.615$) and PU ($r=0.785$) showed large effects, suggesting these differences are unlikely to be due to chance from the small subgroup size, while PEU showed a negligible effect ($r=0.123$), consistent with its non-significant result. These findings indicate that non-experienced participants rated the template-based design more favourably than experienced participants, particularly on PU and ITU, reflecting strong initial acceptance among less technical users within this preliminary evaluation. Collectively, these findings reinforce

the potential of the EduCATE-AR template, particularly for novice AR creators seeking simplified authoring pathways.

B. Thematic Insights from Educators' Reflections

Responses were manually coded using predefined categories mapped to TAM's three core constructs, which are PU, PEU, and ITU. Fig. 6 presents the thematic breakdown and frequency based on the qualitative educators' responses. In terms of PU, educators highlighted that the low technical barrier ($f = 6$) of the EduCATE-AR template made it suitable for non-programmers and novice AR content creators. One educator noted, "The template helps people who've never made an AR app before, especially for teachers who are not good with technical things", proving how the template opens up AR content creation to a broader, less technical audience. This reinforces its accessibility for educators who typically struggle with coding-based platforms. Pedagogical structuring ($f = 4$) was also appreciated for simplifying AR development. This was captured in remarks like, "All is suitable in the template and helps navigate my application well from one module to another", suggesting that the template's design included built-in sequences to support AR lesson progression. This aligns with the goal of helping educators structure their lesson content systematically. Moreover, some educators expressed a desire for scalability and expandability ($f = 3$), particularly with multimedia support. One respondent mentioned, "It's good for now, but I'd like to be able to add videos or maybe audio in future applications", signaling the potential of the template to support more immersive experiences if equipped with richer media capabilities. Also, the template was seen to accelerate development ($f = 2$), with the support of a comment, "Because it is easy to use the template, maybe I can make AR app faster". This suggests that the predefined structure in the template helped users move from concept to implementation quickly.

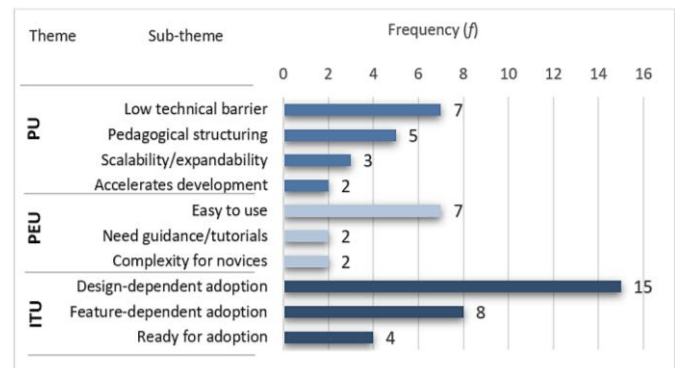


Fig. 6. Frequency of sub-themes across educators' responses.

Regarding PEU, the template's ease of use was the most cited benefit, with easy to use ($f = 7$) emerging as the dominant sub-theme. A participant remarked, "Everything inside the template is easy to understand and access," highlighting the structure and labelling of components in the template's hierarchy, which eases the process of AR content creation. Nevertheless, not all experiences were equally straightforward. Under need guidance or tutorials ($f = 2$), one educator suggested improvements, such as a step-by-step walkthrough. This was reflected in the sentiment that "The template is beneficial, but requires different paces among users," pointing to the necessity

of tailored guidance based on their experience levels. Additionally, complexity for novices ($f = 2$) surfaced through the same concern, suggesting that while the template is understandable for some, others may still find the authoring steps confusing without additional help.

Within the ITU construct, design-dependent adoption ($f = 15$) emerged as the most prevalent theme, with educators noting that although the template is promising, adoption depends on improved structure, layout, or navigational flow. One participant commented, “Maybe improve the hierarchy and visual layout of the template, so it can be easier to organize the content, especially if I can use it to apply speech or sensor inputs in AR”, suggesting how usability limitations in the template’s design can constrain adoption. Another group of educators expressed feature-dependent adoption ($f = 8$), emphasizing that their intent to use the template depends on the inclusion of more engaging, interactive functionalities. As one educator noted, “Add more interactions to make it more engaging”, highlighting how richer media elements and interaction capabilities are essential for enhancing learners’ attention. These reflections indicate that pedagogical value in AR content is often tied to the need for improved layout and content organisation, as well as expanding the template’s interactive capabilities to better engage learners. In contrast, a smaller group of educators demonstrated readiness for adoption ($f = 4$), with no further requests for template improvement. This is shown in responses like “I think it’s good to go for now. After I try to adapt it to my project, I’ll see what else is needed”, pointing to satisfaction with the template’s features and potential willingness to adopt.

V. DISCUSSION

A. Usability in AR Content Creation

Educators’ experiences with the EduCATE-AR template underscored the central role of accessibility in AR content creation. Participants consistently highlighted that the template lowered the technical barrier, especially for those without programming experience. The drag-and-drop mechanics and visual organisation of the template, such as colour-coded hierarchies and prefab-based modules, allowed them to focus on content design rather than technical mechanics. This confirms prior findings that *simplified interfaces* enable broader participation in digital content authoring [13, 61]. While the majority of educators described the template as “easy to understand”, a few expressed the need for more structured walkthroughs. These comments reflect a broader expectation among educators that authoring platforms should provide *facilitating conditions*, especially for those with minimal prior exposure to AR development. Offering in-app tutorials, visual cues, or sample scenes allows educators to build confidence and avoid trial-and-error inefficiency [50].

Notably, statistical analysis revealed that less experienced participants conveyed significantly higher scores for PU and ITU than their more experienced counterparts. This suggests that template-based editing with low technicalities may be particularly valuable for novice AR creators, providing a structured yet flexible environment that increases PEU. Interestingly, the absence of significant differences in PEU across experience levels further underscores the platform’s universal usability. In particular, the ability to use pre-

configured prefabs was seen to accelerate development, with educators noting that they could replicate and customise elements quickly, reducing preparation time. Hence, *fast content assembly* was highly valued for accelerating AR application development.

B. Structuring AR Content for Pedagogical Alignment

Beyond usability, participants underlined the importance of *pedagogical structuring* within the AR development process. Educators appreciated how the template supported lesson progression through built-in sequencing based on EL phases across content modules. As noted by one participant, “it helps navigate my application well from one module to another”, indicating that this structuring was especially helpful in supporting clear lesson design, as educators were able to align AR content to predefined learning objectives. Prior work on AR environments has highlighted similar findings, where logical sequencing of authoring steps should reflect the instructional logic recognised by educators to reinforce conceptual clarity and instructional control [62].

However, some participants emphasised that pedagogical structuring must be responsive to subject-specific needs. While the EL and CT integration in the template was seen as generally effective, some educators noted that a uniform instructional framework may not always translate well across disciplines. For instance, one language educator noted that “using one pedagogy for all subjects may not be suitable, especially for activities involving pattern recognition or algorithms”. A science educator raised a similar point, stating that “for subjects like science that have abstract concepts, using activities that focus only on computational thinking might not be suitable”. These responses highlight a broader issue, indicating that although CT can be useful for procedural thinking and problem-solving in technical fields, the AR content design also needs to be adjusted in subjects where conceptual understanding or interpretive thinking is more important [63, 64]. This means that the authoring platform should support diverse interaction modes and pedagogies to ensure that AR content can be tailored to reflect the instructional logic of different disciplines.

Beyond subject-specific responsiveness, *scalability* also depends on how efficiently new content can be authored and reused as adoption grows. Because each module’s scripts and component configuration are decoupled from any particular subject’s content, similar interaction logic should be able to be reused across different virtual objects and markers without modifying the underlying template. This is consistent with how template-based editing has been shown to accelerate content reuse in AR authoring [33]. Scalability reduces the technical effort needed to extend the authoring template to new subjects. At larger scale, however, this would likely need to be paired with a shared library of ready-made content assets across common subject areas, an approach consistent with reusable learning object repositories that reduce the cost and effort of producing new educational content [32, 65], rather than requiring each educator to individually source and configure their own virtual objects.

Moreover, a few educators emphasised the importance of *content organisation* within the AR scene, reporting that purposeful placement of instructional elements should be

considered. This is derived from responses such as “improve the visual layout of the content”. These insights affirm the necessity for content organisation in AR content design. This is linked with established cognitive load theory, which describes the importance of visual coherence in AR learning environments to avoid extraneous cognitive load [66]. While reducing cognitive distractions is valued by some participants, the significance of *multimedia support* was generally acknowledged to facilitate immersion in AR. Several educators mentioned the need for the integration of diverse media types in AR content to support different instructional methods. As an example, a language educator highlighted that audio is an essential element for demonstrating the sound of Arabic vocabulary. These observations are similar to results from prior studies, showing that embedding rich multimedia is key to improving learner satisfaction [66-68].

C. Towards Personalised Content Creation

Based on the responses collected, several participants appreciated the elements of personalisation and flexibility embedded in the template. As noted by one participant, “Everything inside the template is easy to understand and access, which makes it easier to know how to change the components inside the template.” Another participant stated, “I can just switch the given element and use copy and paste with all the elements needed”. The responses indicate that the template enables educators to personalise lessons by selecting the entry point in the EL cycle, pairing it with the corresponding CT practice, and configuring the AR interaction to embed. For instance, some educators might begin with an AR-based experience in Phase 1 (CE) and shift to a non-AR approach, such as written classroom exercises in Phase 2 (RO). This flexibility enables educators to design their own instructional content based on specific learning outcomes or teaching goals [69].

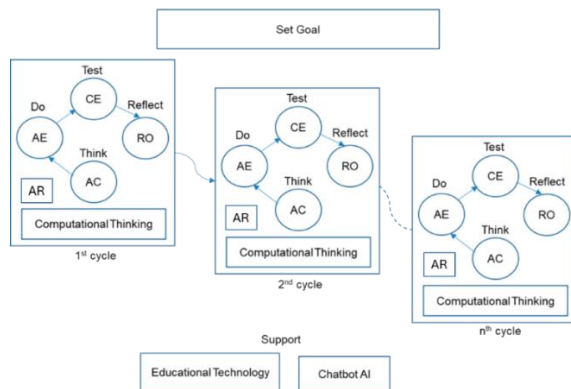


Fig. 7. Additional personalisation layer through Chatbot AI.

Extending this flexibility in content creation, Fig. 7 illustrates how an AI chatbot can add another layer of personalisation to AR content, as a virtual tutor. Since pedagogical agents with human-like assistance have been shown to aid learning [70], such integration can enhance support during the AC phase by providing on-demand explanations or addressing learners' queries with theoretical grounding. Thus, the authoring experience not only allows educators to tailor content flow based on pedagogies but also lays the groundwork for scaffolded and adaptive AR learning experiences, aligned with instructional intent and learner needs [71].

VI. CONCLUSION

This study investigated how a pedagogically structured integration of CT and EL can empower educators in creating AR learning content. By designing and evaluating the EduCATE-AR model, which operationalises CT principles through the EL cycle, this study demonstrated that educators, particularly those with limited technical expertise, can effectively participate in AR content authoring when supported by a theoretically grounded, template-driven model. The model's foundation in pedagogical mapping between computational logic practice and experiential learning design bridges technical and instructional barriers in AR creation. Quantitative results supported the model's practicality, with novice participants reporting significantly higher levels of PU and ITU. Meanwhile, thematic analysis revealed that the model's modularity and prefab-based design approach were especially valued, though participants also highlighted the need for expanded features and greater pedagogical flexibility to accommodate personalisation.

In terms of limitations, the study was conducted within a focused and relatively small participant group, and all evaluations occurred within a guided research setting rather than a classroom setting. As such, the observed acceptance and positive perceptions may reflect initial exposure rather than sustained integration. Moreover, the study focused primarily on educator perspectives, without directly measuring student learning outcomes or classroom impacts. In addition, the prototype version of the template, while functional, did not offer full customisability or extensibility beyond its prefab modules, which limits insights into more advanced usage scenarios.

Future research should extend these findings by examining how educator-authored AR content affects real classroom environments over time. Longitudinal studies could assess whether the initial motivation and intention to use translate into continued use and improved instructional outcomes. Future evaluations should also incorporate specialised instruments, such as cognitive load assessments, pedagogical alignment rubrics, or CT skill integration metrics, to more directly assess whether the EL-CT theoretical grounding achieves its intended instructional goals, beyond the acceptance-level evidence captured by TAM. Moreover, involving students in future evaluations will be crucial to understanding how educator-authored AR experiences affect engagement, comprehension, and knowledge retention. Expanding the AR authoring template design to support a wider range of pedagogical strategies will also help ensure broader applicability. In addition, performing a controlled comparative study with an existing AR authoring tool would help isolate the specific advantages of embedding EL and CT directly into the authoring workflow. Finally, incorporating adaptive features such as real-time guidance during authoring or AI-based design recommendations could further support educators in aligning their AR content with instructional goals. Such enhancements would not only deepen the educational impact of immersive technologies but also lay the foundation for more personalised, learner-centred AR experiences.

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