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A Novel Instructional Design Model for Developmental Researchers and Instructional Design Practitioners in Pattern Construction Open Education

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Abstract

Advances in fashion pattern construction technologies continually introduce novel approaches that address the limitations of existing practices. To keep pace, these emerging technologies must be widely disseminated to update practitioners' skills and advance current practices. The literature identifies two primary dissemination methods: the traditional instructor-led method and the learning management systems-based open educational resources (LMS-based OER) method. The former, heavily reliant on apprenticeships for technical skill development, is inefficient, ineffective, and unsustainable. In contrast, the OER-based approach offers a more efficient, effective, and sustainable alternative, positioning it as the superior method for disseminating emerging technologies in this field. However, the effective establishment and implementation of effective OERs require an OER-oriented instructional design model (IDM) tailored to the specific learning needs and large-scale adoption theories pertinent to pattern construction. Currently, such a model is absent, hindering the field's transition to a theory-based dissemination approach customised to its unique practices and impeding the efficient, widespread adoption of novel pattern construction technologies. Using a developmental approach, this study addresses this gap by introducing a novel OER-oriented IDM termed OER-PattEdu. This study contributes to both theoretical and methodological literature and holds practical implications for transforming lifelong learning and professional development in the field into a more efficient and sustainable paradigm.

Keywords: Instructional design model, open education, open educational resources, open learning management platforms, pattern construction, Sustainable and efficient educational paradigm.

1. Introduction

Pattern construction education emerged as a specialised domain within fashion education to underscore its critical role in key fashion sectors such as fashion design, garment manufacturing, and textile engineering [1]. Pattern education involves teaching fundamental concepts and skills for creating and manipulating well-fitting patterns, which form the bedrock of garment cutting and production [1]–[4].

Traditional pattern construction methods, currently prevalent in academia and industry, have been identified as inefficient and unsustainable [2]. However, advances in pattern construction technologies contentiously introduce novel, more sustainable, and efficient alternatives [2]. Consequently, a growing demand exists to disseminate these advances to shift the pattern construction industry and academia to a more efficient and sustainable paradigm [2], [5], [6].

Traditional educational methods for disseminating new technologies heavily rely on costly apprenticeships that deliver technical skills through on-the-job training, rendering them inefficient, ineffective and unsustainable for large-scale dissemination [7]. These limitations have hindered the wide adoption of superior approaches, contributing to the persistence of traditional pattern construction methods and their associated environmental and economic challenges [7].

Educators have introduced OERs as a more sustainable and efficient alternative for widespread dissemination [8], [9]. OERs refer to any digital learning content available online for lifelong learning at no cost [10]–[12]. They include modules, videos, e-textbooks, and other digital educational tools that embed a theoretical and technical understanding of pattern construction practice [8], [13]–[17].

OERs are also one of the open education methods rooted in the conviction that education should be open, free, and accessible to all individuals seeking knowledge and learning opportunities [18]. Fashion educators such as Paola Bertola, Angelica Vandi, Jo Conlon, Simeon Gill, Hailah Al Houf and Steve Hayes strongly advocate for open fashion education as a necessary paradigm for reforming, reshaping, and revolutionising the 21st-century fashion educational systems and industries [8], [19], [20]. OERs are a method of open education and of paramount importance, especially in light of the rapid evolution of pattern construction technologies, necessitating lifelong skill development. Educators have empirically examined the effectiveness, efficiency and sustainable potential of OERs for the large-scale dissemination of emerging pattern construction technologies, confirming their potential in these areas. [8], [9]. For example, Conlon et al. (2024) established open LMS-based OERs to disseminate the conceptual and technical knowledge of pattern parametrisation, a technology that generates responsive and dynamic fashion patterns [2]. Based on the outcomes of their study, Conlon et al. (2024) confirmed that LMS-based OERs enable sustainability, effectiveness and efficiency objectives in large-scale knowledge dissemination. This could justify the inclusion of OERs as a central component of the United Nations' 2030 sustainable development agenda [21].

Nevertheless, establishing effective LMS-based OERs requires an IDM that promotes the integration of open LMSs with OERs and is underpinned by this modality's learning and technology adoption theories [9]. An IDM is a design framework that offers a theoretically grounded, goal-oriented, and systematic approach to creating effective learning experiences that facilitate the acquisition of novel technologies' concepts and skills and the development of positive attitudes towards their adoption [9], [22].

Empirical research supports the need for such a model. For example, Aldosari, Eid, and Chen (2022) investigated the impacts of integrating OERs with LMS into an existing IDM to enhance the dissemination of emerging technologies. They concluded that it is essential to develop novel IDMs that promote the use of LMS-based OERs because they are a strategic enabler for achieving sustainability, efficiency, and effectiveness in the dissemination of emerging technologies across different industry and academic environments.

Such a model is currently lacking, hindering the field's transition to a theory-based diffusing approach customised to its unique practices and needs. This absence has also impeded the effective and widespread dissemination of novel pattern construction technologies, slowing down their wide adoption and prolonging the dominance of outdated technologies.

This study aims to address this need by introducing a novel OER-oriented IDM customised to the prerequisites of the large-scale dissemination of pattern construction emerging technologies and underpinned by this modality's supporting theories. This IDM is termed OER-PattEdu: shortcut OERs for pattern education.

The OER-PattEdu is grounded in the theories underpinning LMS-based pattern construction education and the adoption of emerging technology. It also addresses the unique requirements of OERs and provides solutions to challenges identified in pattern construction learning. OER-PattEdu also enables data to be collected on learners' comprehension of learning and their intentions to apply it in real-world scenarios within the same context.

2. LITERATURE REVIEW

A. The Large-Scale Dissemination Methods of Emerging Pattern Construction Technologies

The extant literature on pattern construction identifies two primary methods for disseminating emerging technologies at a large scale: traditional instructor-led and open LMS-based OERs [8], [23]. According to Van Hung, Tuan and Tuyet (2024), the superiority of one method over another depends on the large-scale lifelong learning requirements: sustainability, effectiveness, and efficiency. Research confirmed this assertion, emphasising that only empirical evidence derived from experimental comparisons between dissemination methods can determine their superiority [24]. Consequently, this section conducts a comparative analysis of these two existing dissemination methods to identify the optimal one for disseminating emerging pattern construction technologies on a large scale. This analysis was carried out by drawing from existing empirical comparative studies.

In terms of sustainability, concerning reduced labour intensity and cost-effectiveness of the dissemination process [25], OERs emerged as a more sustainable modality for large-scale professional development and lifelong learning than their traditional counterpart [25], [26], particularly in the pattern construction field [8]. In this regard, the human capital and costs needed for dissemination at a large scale [27], pattern construction professionals and academics worldwide need to continuously update their knowledge, skills, and competencies to stay aligned with the requirements of the rapidly changing fashion industry and academia [8], [28]. When developed and deployed online, OERs provide free and accessible resources that can be utilised anytime from anywhere to acquire the concepts and technical skills necessary for understanding emerging technologies and applying them to advance current practices [8], [26]. This approach circumvents the financial barriers associated with traditional formal training, including tuition fees and the costs of physical training materials and facilities [29]. Unlike instructor-led training, this approach also fosters independent, learner-centred education, empowering professionals to upskill at their own pace without the need for the presence of instructors [30].

Despite their sustainable potential compared to traditional methods, OERs are not without limitations. Challenges such as the ongoing requirements for maintenance and inadequate technical infrastructure could challenge the longevity of OERs and restrict their widespread access and utilisation [31]. Nevertheless, the development of LMS-based OERs can mitigate these challenges.

Learning effectiveness is also a key determinant of the optimal dissemination method [32]. Learning effectiveness refers to the learners' active engagement in learning experiences that facilitate the acquisition of novel knowledge and skills and transfer them to real-world work environments [33]. To ensure active learner engagement, the dissemination method should be learner-centred and experiential [34]. Such a method positions learners at the core of the educational process, fostering critical thinking and problem-solving abilities that inform decision-making in the active learning situation and other relevant situations [34].

In this context, the instructor-led method is often considered ineffective for diffusing new technologies [32]. This ineffectiveness arises from learners' passive role in the learning process and the heavy reliance on ineffective techniques for knowledge dissemination, such as passive observation and note-taking[26]. This passivity hinders the high level of engagement necessary to develop essential skills for understanding and applying novel technologies to advance current practices, such as critical thinking, problem-solving, and creativity [8], [35]. This also restricts learners' capacity for independent lifelong learning, which is crucial for professional development and the adaptation of future innovations [8], [26].

OERs, in contrast, are inherently learner-centric and experiential [8], [26]. They actively engage each learner in a real-life problem-solving project, applications and tutorials, enabling him to use the technology to construct a complete pattern project [8], [36]. This active learning method promotes a deeper understanding of novel technologies' principles, their applications and potential to challenge outdated practices and address their limitations [8], [26], [37], [38]. OERs, therefore, are particularly effective in cultivating critical thinking and problem-solving abilities, essential for advancing the field [8].

Empirical studies have substantiated the effectiveness of OERs in enhancing critical thinking and problem-solving skills. For example, Sulisworo and Syarif (2018) investigated the impact of OERs on the critical thinking abilities required for problem-solving. The researchers assembled some problem-solving activities related to a specific issue and integrated them into OERs. They subsequently engaged students with these activities and measured the impact of this engagement on their critical thinking skills using pre- and post-surveys. Their findings indicate that OERs offer a more effective learning experience than traditional methods. According to

Sulisworo and Syarif (2018), OERs' effectiveness stems from their ability to foster critical thinking and reflection on current practices and demonstrate the potential of novel technologies to evolve them and address their limitations.

On the problem-solving side, Conlon et al. (2024) provided empirical evidence on the effectiveness of OERs in disseminating emerging pattern construction technologies to solve the problem of current pattern construction practice and shift the field towards a more sustainable and efficient paradigm. The researchers embedded the conceptual and technical frameworks of pattern parametrisation into OERs. Pattern parametrisation, a recently emerging technology in pattern construction, has the potential to address issues in current practices, such as unsustainability, inefficiency and environmental concerns [2]. Importantly, disseminating such emerging technologies to promote sustainability, efficiency, and effectiveness in pattern construction requires dissemination methods that are equally sustainable, efficient, and effective. OERs, as a readily available dissemination method, embody these characteristics, making them the optimal choice for such purposes.

Another important superiority factor of the dissemination methods is their capacity to enhance creativity by breaking away from traditional approaches to pattern construction. In this regard, OERs are found to be a strategic enabler of creativity due to their openness and transdisciplinarity [8].

Openness in higher education can be defined as the practice of breaking down boundaries not only within the discipline's subsectors but also opening external borders to all actors in other industries and public society [19]. Fashion educators, such as Paola Bertola and Angelica Vandi, strongly advocate for openness as a necessary approach for reforming, reshaping, and revolutionising the 21st-century fashion educational systems and industries [19], [20]. In that respect, Conlon et al. (2024) released open LMS-based OERs teaching pattern construction approaches. An analysis of their research sample revealed that individuals from more than fifteen academic disciplines and hobbyists from the public community were engaged in pattern construction activities and seeking opportunities to learn the conceptual and technical knowledge of this field.

Regarding transdisciplinarity, it entails the synthesis of knowledge and competencies derived from diverse disciplinary perspectives to generate novel insights to advance the field and address its challenges that cannot be resolved through single-discipline knowledge alone [39]. Fashion educators have underscored transdisciplinarity as a pivotal shift from a product-centric to an innovation-focused education [19], [20]. They believe that transdisciplinarity is a key enabler in continuously advancing pattern construction knowledge and methods by adopting new applicable approaches and technologies [20].

Conlon et al.'s (2024) study also evidenced the multidisciplinary nature of pattern construction and the interest of other disciplines in it. For example, participants with backgrounds in computer science joined their study due to their interest in developing novel patternmaking drafting and automation systems. Such engagement fosters a more collaborative and inclusive approach to driving overall growth and development within the field.

Accordingly, the development of an OER-oriented IDM has the potential to promote the use of LMS-based OERs in disseminating emerging superior alternatives and ground their development in theories that support adopting their contents [9]. Aldosari, Eid, and Chen (2022) developed a strategy combining existing IDMs and OERs and tested their impacts on the dissemination of new technologies. They concluded that OERs are an optimal strategic enabler for the effective, sustainable, and efficient dissemination of emerging technologies and their innovative approaches. This conclusion led the researchers to advocate for the development of novel IDMs that not only promote the use of OERs as a dissemination strategy but also ensure their theoretically grounded and goal-oriented development.

This section extends the existing literature on the dissemination of emerging pattern construction technologies by critically examining the suitability of existing dissemination methods, namely, instructor-led approaches and OERs, in terms of their optimality for sustainable, efficient, and large-scale dissemination. The objective is to promote the adoption of best practices that facilitate the widespread dissemination and enhanced adoption of cutting-edge technologies in pattern construction.

B. Pattern Construction Learning Requirements

Identifying the requirements of pattern construction learning could be an effective starting point for developing a theory-based IDM. This identification provides a pathway for the development of a more targeted IDM that effectively addresses these needs and supports and informs the selection of learning theories that enhance the field’s pedagogical practices.

Pattern construction learning encompasses diverse requirements, reflecting its multifaceted nature and varying learning domains. Gagné [40] identified five domains that influence any learning process and define the requirements of pattern construction learning: motor skills, verbal information, intellectual skills, cognitive strategies, and attitudes [40]. These domains are crucial in shaping the effective learning experience and must be carefully considered to ensure effective instructional design.

Motor skills demand repetitive practice for mastery [40], [41]. This domain is central to pattern construction learning, as all its activities fundamentally involve and necessitate hands-on experimentation [3]. This includes constructing, manipulating, and creating patterns, requiring engagement with pattern construction technologies and practice of their technical methods. Therefore, its instructional tools must be supplemented with practical, hands-on training not only to address the needs of the motor skills learning domain but also to effectively bridge the gap between its theories and practice, one of the key challenges identified in pattern construction learning [42].

Verbal information refers to conceptual knowledge and theoretical underpinnings of pattern construction [40], [41]. Effective instructions for verbal information require the careful organisation of information into coherent, logically structured sequences presented within meaningful contexts [40], [41]. This domain warrants particular attention when developing IDMs for pattern construction education due to its inherent conceptual complexity. The intricacies of techniques, such as spatial reasoning, parameterisation, proportions, and fabric behaviour [2],

[6], [8], [23], [43]–[45], demand a well-structured approach to facilitate deep learning and knowledge retention.

Intellectual skills involve elaborating on basic rules of pattern construction [40], [41]. An example of intellectual skills in this field is the application of equations and drafting rules to establish the body-to-pattern relationship when creating patterns. Pattern construction demands a high level of intellectual skill due to the complex interplay between various factors, such as pattern geometry, body anatomy, proportions, and fabric behaviour [2], [6], [23], [43]–[45]. Each rule must carefully account for these elements, as overlooking any of them will likely result in poorly fitting patterns [2]. The intricate nature of these factors presents significant intellectual challenges in pattern construction education [23], [43]–[45], necessitating careful consideration when developing specialised IDMs.

Cognitive strategies refer to the internalised skills that govern learning behaviours, knowledge retention, critical thinking and problem-solving abilities [3], [40], [41]. These strategies are cultivated through practice, either through learners' reflection on their experiences or by employing instructional design strategies that actively promote their development [40], [41].

In contrast, attitudes are not acquired through practice but rather through modelling, reinforcement, and feedback [40], [41]. Attitudes significantly influence learners' motivation to engage with, transfer, and apply learning [41]. For example, a learner who is interested in pattern construction is more likely to develop a positive attitude towards mastering new innovations and transferring them into professional practice.

Recognising and accounting for these distinct learning domains is essential for developing an IDM tailored to the unique requirements of pattern construction education. It is crucial to support this model with instructional design strategies that address the specific needs of each domain and the associated challenges, making them explicit to instructional practitioners and developmental researchers. This approach is vital to ensuring the creation of impactful instructional tools. Such a supported model is not only important for fostering long-term knowledge retention and enhancing problem-solving skills but also for effectively disseminating the latest scientific and technological advancements in the field and promoting their adoption.

C. Theories Supporting OER-based Dissemination of Emerging Pattern Construction Technologies

Grounding OER-oriented IDMs in theories that support the dissemination and adoption of emerging pattern construction technologies is crucial. This approach enables the development of OERs based on a critical understanding of learning mechanisms that effectively meet the requirements of pattern construction learning domains and address the inherent challenges and complexities of the field, as discussed in Section C. In doing so, it facilitates the comprehension and, hence, the large-scale adoption of emerging technologies. A review of the relevant literature identified two key groups of supporting theories: learning theories and technology adoption theories.

1) Learning Theories

Learning theories are built on a critical theoretical understanding of the cognitive processes involved in learning [46]. In learning, three types of memories, sensory, working, and long-term, interact to process, encode, store, and retrieve information, as illustrated in Figure 1 [41].

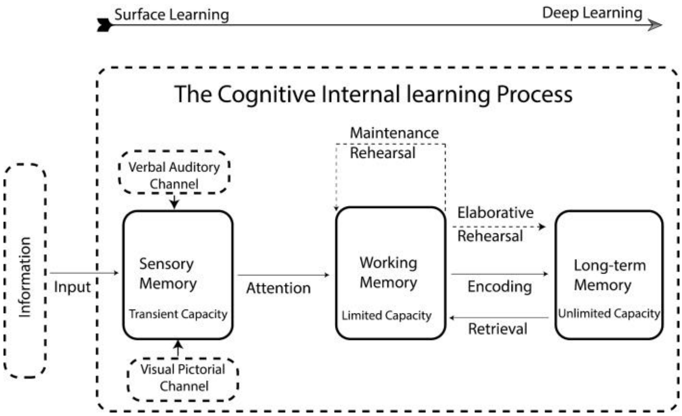

Figure 1 Learning cognitive process based on [41], [47], [48]

As Figure 1 shows, sensory memory initiates the learning process by transiently collecting information from the learning environment through auditory and pictorial channels. If the learner pays attention to this collected information, it progresses to processing and temporary storage in the working memory, which has a limited capacity. The limitation of working memory is a critical factor to consider when designing instructional resources [41], [48], [49].

While processing information in the working memory, learners utilise two types of rehearsal. The first is maintenance rehearsal, where learners memorise information without thinking or deeper cognitive engagement. This leads to short-term retention and surface learning and hinders the transfer of information to long-term memory [41]. The second type is the elaborative rehearsal, where learners understand information and organise it, facilitating meaningful learning and enabling the transfer of information to long-term memory. This long-term memory has unlimited capacity and permanently stores information in organised schemas, which can later be retrieved into working memory as needed.

Many learning theories have been developed based on this learning mechanism to elucidate why and how learning occurs [50]. Discussing these theories within the context of this study is important to inform the selection design strategies that not only promote knowledge acquisition but also facilitate the adoption and application of learning in both personal and professional contexts [41], [51]–[53]. This discussion also enables the prediction of the selected strategies' impacts on learning, providing a theoretical framework for their assessment.

Lefrançois (2019) emphasised evaluating theories based on their relevance and applicability to specific educational practices rather than their absolute correctness. Following this perspective, this section critically examines several educational theories that support the effective acquisition and transfer of knowledge in pattern construction. As the core objective of designing OERs for pattern construction is to disseminate innovative technologies that offer superior alternatives to current practices at a large scale, the integration of these theories is essential to ensuring that learners not only master the concepts and technical skills involved but also apply them effectively in real-world contexts.

In the context of open LMS-based OERs design for pattern construction, learning theories can be categorised into three main groups: primary human learning theories, higher education human learning theories, and web-based learning theories [8], [41], [51], [54].

The primary human learning theories supporting instructional design are behaviourism, cognitivism, and constructivism [41], [51], [54]. Each theory conceptualises learning and the roles of learners from a different perspective, which in turn necessitates the adoption of varied learning delivery and assessment strategies [41], [51], [54], [55], as illustrated in Table 1.

Table 1 The primary human learning theories underpinning OER-oriented instructional design for pattern construction

Theory	**Behaviourism**	**Cognitivism**	**Constructivism**
Learning Concept	Acquisition of new behaviours from external resources.	Acquisition and reorganisation of cognitive structures.	Search for meaning through experience.
Learner's Role	Passive, limited to receiving information from external sources.	Active participation to understand processes.	Active participation to understand and reflect on processes.
Delivery Strategy	Programmed instructions like OERs.	Concept mapping.	Problem-based learning.
Assessment Strategy	Criterion-referenced multiple-choice questions.	Task-based assessments.	Standardised tests.

Underpinning the OER-PattEdu with these theories is crucial. It supports the creation of effective, learner-centred educational tools that cater to pattern construction learners' diverse learning needs and preferences, ensuring that learners can progress from basic skill acquisition to advanced, reflective practice. It also enables measuring learning goal achievement by assessing conceptual and technical knowledge acquisition [56].

Higher education learning theories are also essential theoretical foundations prioritised by developers of IDMs in higher education contexts [41], [57]. Among these, adult learning theory is paramount, as it is grounded in principles of independent learning and andragogy, which are indispensable at this level [41], [58], [59]. Andragogy is the science of fostering adult learning and underscoring the importance of its autonomy [60], [61].

A key principle of adult learning theory is the analysis of learners' entry behaviours, such as their prior knowledge, skills, and personal or professional learning goals [58]–[61]. This analytical approach enables the customisation of instruction, ensuring that it builds upon learners' existing capabilities and addresses their specific needs[41]. It also informs the selection of learning delivery strategies aligned with the educational tool's developmental objectives [58]–[61].

Another core principle of the adult learning theory is promoting active learner engagement by selecting delivery strategies that foster experiential learning [58]–[61], a core domain and mandatory requirement for effective pattern construction learning. For experiential learning to be effective, it must be contextualised in real-world settings, enabling learners to participate in relevant and meaningful activities [62]. This is an intersecting principle between the adult learning theory and the situated cognition theory, which also asserts that learning is most impactful when embedded in authentic contexts, fostering both knowledge retention and transfer [63], [64].

In the context of pattern construction, situated cognition theory is particularly relevant, as it supports not only the professional application of technology but also a deeper understanding of its underlying principles [65]. This approach is essential for bridging the often-identified gap between theoretical knowledge and practical application [62] identified in traditional pattern construction learning [42]. By integrating both theory and practice, situated cognition enhances the learner's ability to apply knowledge effectively in professional contexts, which is the main aim of developing educational tools for diffusing emerging pattern construction technologies.

Web-based learning theories, particularly Cognitive Load and Multimedia Learning Theories, are fundamental to designing OERs for pattern construction [8]. These two theories are cohesively related, and some studies have even merged them into a single theory, known as the cognitive theory of multimedia learning [48], [49]. Both theories are rooted in the cognitive learning process, described in Figure 1 [41], [66].

Cognitive load theory suggests that any learning process generates three distinct types of cognitive load: intrinsic, germane, and extraneous [41], [48], [49], [66], [67]. Intrinsic load arises from the subject matter's inherent complexity and interconnectedness. Germane load relates to the cognitive effort necessary to reach a learning objective, encompassing higher-order thinking processes such as analysis, comparison, and synthesis of steps required to master the learning content. These activities facilitate the integration of new information into a schema of well-connected ideas, promoting deeper understanding. Extraneous load, conversely, represents the unnecessary cognitive burden that hinders learning, typically stemming from poorly designed instructional materials or ineffective presentation methods.

Multimedia Learning Theory complements Cognitive Load Theory by offering an instructional approach rooted in a comprehensive understanding of the learner's cognitive architecture, specifically, how information is received, processed, and stored [48], [49], [66]. This approach lies in enhancing the simultaneous use of the working memory's input channels (auditory and visual) to optimise the working memory, enhance extraneous cognitive load, manage intrinsic cognitive load, and enhance germane load [48], [49], [66]. This dual-mode presentation enhances the acquisition and retention of new skills, making learning more effective [68]. [69]. It also caters to different learning styles and preferences [69], addressing the mismatch between learning and teaching styles identified as a key issue in learning pattern construction [70]. When instructional design fails to incorporate these considerations, they often impose unnecessary cognitive demands, increasing extraneous load and diminishing the effectiveness of the learning process [41].

Conlon et al. (2024) provided empirical support for the critical role of these theories in enhancing digital pattern construction learning efficiency and retention [8]. Their research focused on designing OERs to teach pattern parametrisation on a large scale. Pattern parametrisation is a geometric approach that links pattern inputs to outputs via parameters, thus generating adaptive and responsive patterns[2], [6]. They employed a dual-mode instructional approach to explain the process of pattern parametrisation using auditory explanations synchronised with visuals, motion graphics and concept maps. Their findings confirm the significant impact of multimedia and cognitive learning theories in facilitating the acquisition of novel conceptual knowledge and technical skills in pattern construction.

2) Technology Adoption Theories

Technology adoption theories must not be overlooked when developing an OER-oriented IDM for pattern construction. This is because pattern construction is often coupled with computer-aided design (CAD) technologies [75], bringing additional challenges to the learning process, such as resistance to new technology and adopting its approaches, concepts, and technical. Also, OERs themselves are educational information technologies typically delivered through digital educational environments. Therefore, incorporating technology adoption theories can significantly enhance the likelihood of successfully adopting the OERs, their contents, and associated technologies and mitigate the risk of rejection [76].

There is a wide range of technology adoption theories available, and each explains the constructs shaping users' acceptance of new technology [77]–[81]. However, in the context of pattern construction-related education, the Technology Acceptance Model (TAM), originally formulated by Davis, Bagozzi and Warshaw[81] and modified by Venkatesh and Davis [82], is the predominant theory. Figure 2 illustrates how technology acceptance by users is conceptualised from the perspective of TAM.

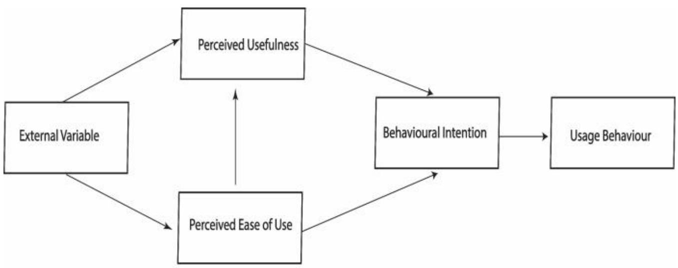

Figure 2 The last version of the TAM Model (Davis & Venkatesh, 199, p.20)

As the Figure shows, the adoption process commences with an external motivator, where instruction can be strategically positioned [83]–[87]. This could justify the predominance of TAM in educational research. According to TAM, if the instruction enhances the perceived usefulness of the novel technology and facilitates the acquisition of its conceptual and technical frameworks, it will effectively influence the behavioural intention to adopt and apply the learning. This behavioural intention, according to TAM, leads to the actual use behaviour. Empirical evidence from educational research concerning the role of TAM in facilitating learning acquisition, adoption, and application supports the importance of grounding the OER-PattEdu in TAM. Their outcomes suggest that equipping the IDM with robust strategies that explicitly emphasise the consideration of the antecedents influencing the adoption intentions can optimise the likelihood of successful learning adoption and transfer to professional practices.

The key message of this discussion is that instructional design practitioners and researchers must critically understand how learning occurs and how learners' intentions to adopt new technologies can be influenced and then apply strategies that enhance these processes. They should carefully curate the information prioritised by sensory memory during the learning process when designing OERs and employ strategies that facilitate effective processing and long-term storage. By doing so, they optimise working memory and balance the cognitive load across different cognitive processors (visual and auditory), thereby preventing cognitive overload by eliminating unnecessary content[48], [49].

They should consider designing OERs that incorporate strategies that mentally organise learning materials and present them coherently, facilitating their integration with learners' pre-existing knowledge, as Mayer and Moreno (2003) recommended. The inclusion of strategies that promote deep understanding and reflection, rather than rote memorisation, would support the elaboration process, enabling more effective encoding of learning content. This, in turn, facilitates successful transfer and application in practical working environments, aligning with the overarching aim of establishing OERs embedding emerging pattern construction technologies.

D. Instructional Design Science

Having examined the theories related to how individuals learn and adopt novel technologies, it is imperative to investigate the pivotal role of instructional design science in facilitating this process. Instructional design science is a specialised field dedicated to the selection and employment of effective design strategies that operationalise these theories [41]. This means that instructional design is the connective bridge that translates the underlying theories into practical learning applications. Therefore, instructional design practitioners should carefully select and employ instructional design strategies that can stimulate appropriate cognitive processes within learners, thereby achieving more successful learning outcomes [41].

Scientific and effective instructional design has five scientific principles that make instructional materials meaningful and goal-oriented [41], [88], [89]. These principles are: 1) engaging learners in solving real-world problems, 2) leveraging their existing knowledge as a foundation for new knowledge, 3) effectively demonstrating new knowledge to learners, 3) ensuring learners tend to apply new knowledge, and 5) ensuring learners tend to integrate new knowledge into their real-world contexts.

A critical analysis of these principles confirms that effective instructional design is rooted in a profound understanding of how individuals learn and adopt new technologies. It is, hence, theory-based, and its principles are derived from and driven by the learning and technology principles of their underpinning theories from Section C, as illustrated in Table 2.

Table 2 The principles of instructional design science and their underpinning theories from Section C.

Principle	Underpinning Theory
Engaging learners in solving real-world problems.	Constructivism, cognitivism, adult learning, and situated cognition theories.
Leveraging learners' existing knowledge as a foundation for the new knowledge.	Constructivism and adult learning theories.
Effectively demonstrating new knowledge to learners.	Behaviourism, cognitive load, multimedia learning theories.
Ensuring new knowledge is applied by learners.	TAM
Insuring learners tend to integrate new knowledge into their real world.	TAM

This alignment validates the selection of supporting theories discussed in Section C to underpin the novel IDM established in this study. However, it is noteworthy that these principles assume a uniform educational background among all learners. Consequently, they should be further customised to align with the characteristics of pattern construction OERs users. Conlon et al. (2024) confirmed that pattern construction OERs are accessed and utilised by individuals from diverse educational backgrounds, including computer science learners interested in pattern construction CAD systems. Therefore, the principle concerning building new knowledge on existing knowledge should be reconsidered. Learners lacking this foundational knowledge should be provided with non-overwhelming and relevant experiences to serve as a basis for the new knowledge [90]. This study extends the existing literature by evaluating the science of instructional design and its guiding principles within the context of OERs-based and large-scale pattern construction education.

Existing IDMs have been developed based on these principles and their underlying theories. Lee & Jang (2014) classified existing IDMs into two groups: conceptual IDMs and procedural IDMs [91]. Conceptual IDMs offer a macro-level, theory-driven perspective of key variables and their interrelationships. In contrast, procedural IDMs provide a micro-level view of detailed procedures, actual design activities, and guidance on task execution. Notably, procedural IDMs are always grounded in conceptual IDMs[91].

While numerous IDMs exist, this analysis will focus only on the analysis, design, development, implementation, and evaluation model (ADDIE), the four-component IDM (4CD), and the Elgazzar IDM are discussed here due to their tested applicability in pattern construction education [71]–[74]. The ADDIE model is a conceptual model grounded in behaviourism and uses a behavioural approach to design instructions [41]. It is also the most straightforward and user-friendly of the three models. The 4CD model is also a conceptual model rooted in the cognitive load theory and uses a cognitivist approach to design instruction [41]. The Elgazzar model is a procedural model comprised of six key variables (analysis, design, production and construction, evaluation, and use) and their interrelationships, along with detailed procedures and actual design activities associated with each variable [92]. The Elgazzar model is grounded in the cognitive load of multimedia learning theory and framed by the principles of e-learning and distance education [92].

While the applicability of these models in pattern construction has been demonstrated, their suitability and effectiveness for pattern construction open education, particularly open LMS-based OERs-facilitated education, have not been tested yet. Also, the suitability of the ADDIE and 4CD models for contemporary educational approaches has been questioned due to their obsolescence [22], [93]. Regarding the Elgazzar model, it is an administrative model designed to support the development of synchronous e-learning environments. This confirms the research problem of this study concerning a lack of specialised IDMs grounded in a deep understanding of the unique requirements and challenges of pattern construction education. These IDMs also fail to account for the merely learner-centred and asynchronous nature of open educational environments.

Nevertheless, a key finding from the examination of these IDMs highlights that effective instruction necessitates the following sequential phases: analysis, design, development, implementation, evaluation and use. The analysis phase entails reviewing existing knowledge to identify both conceptual and technical knowledge gaps and establishing an instructional aim to address them [71]–[74]. The design phase involves establishing the conceptual and technical frameworks that bridge the identified knowledge [71]–[74]. This phase also includes establishing the assessment instruments that measure instruction comprehension, adopting and applying them in real-world contexts [8], [71]–[74].

The development phase focuses on procedural activities of establishing the instructional tool that embeds the established instructional content and its hosting environment [71]–[74]. This includes dividing the learning content into short units, digitising them into various multimedia resources (texts, audio, visual representations), developing the hosting environment, and loading the resources into it.

The implementation phase involves engaging the targeted audience with the instructional tool and collecting empirical data to assess the extent to which instructional objectives have been met [71]–[74]. The evaluation phase includes analysing the collected empirical data to assess aim achievement [71]–[74]. The use phase involves using the evaluation phases' outcomes to generate solutions for future applications [71]–[74].

As for the shortcomings of existing models for large-scale pattern construction open education, this study introduces a novel IDM tailored to support this approach. This IDM offers developmental researchers and instructional design practitioners in pattern construction open education a systemic approach to achieving their goal of designing open LMS-based OERs for this field.

3. METHODS

A. Study Design

Studies on IDMs can be classified into model development, model validation, and model employment [94]. This study falls into the first category and employs a developmental approach rooted in instructional design principles and pattern construction open education theories to create the OER-PattEdu model.

The methodology for OER-PattEdu development was informed by previous multidisciplinary studies that developed novel IDMs for digital learning in higher education [41], [94]–[98]. According to these studies, novel IDMs can be developed through theoretical or practical design approaches or a combination of both. The theoretical approach involves synthesising relevant literature, while the practical approach utilises task-simulation design, also known as real-world design projects.

The OER-PattEdu in this study was developed through a hybrid approach synthesising relevant literature and task-simulation design. The approach of synthesising relevant literature drew upon existing research on IDMs, learning theories, and best practices for developing OERs in pattern construction. It involved examining, analysing, and combining findings from various studies to create the OER-PattEdu. The task-simulation design approach, conversely, focused on practical activities needed to develop and use OERs that mirrored real-world tasks and situations. The theoretical approach ensured the robustness of OER-PattEdu, enhancing its credibility and reliability. Meanwhile, the task-simulation design approach demonstrated effectiveness in developing practical skills and competencies directly applicable to real-world situations [99]. It also guarantees that OER-PattEdu will produce engaging, context-specific OERs for pattern construction, making it highly relevant to the field [100].

B. Development Procedures

The development of the OER-PattEdu model followed a constructive approach that aligned with the approaches used for IDM development in the relevant literature [41], [94]–[98].

The development of the OER-PattEdu model began by identifying its core phases. These phases are discussed in Section II.E as the essential phases for the creation and implementation of effective OERs to address gaps and problems in the field: analysis, design, development, implementation, evaluation, and use.

This was followed by defining theory-underpinned procedural activities for the phases and establishing their interrelationships, aligning with findings from the relevant literature discussed in Section II.E. Each phase logically builds upon its predecessor and paves the way to the next one. This does not mean the model is strictly linear, as certain phases still influence others, providing opportunities for feedback and improvement.

The model begins with the analysis phase, which serves as a foundational step. This phase involves identifying conceptual and technical knowledge gaps in existing literature, thereby establishing the instructional objectives for the subsequent phases.

Following the analysis phase is the design phase, where instructional content is created specifically to address the identified gaps. This phase also includes designing instruments to assess learners' comprehension of learning and intentions to adopt and apply it in real-world situations (Behaviourism).

The instructional content is then transformed into audio-visual OERs (Multimedia learning theory) hosted hierarchically (Cognitivism) on an open-LMS platform (Openness) during the development phase. It also included dividing the established content into bite-sized units (Cognitive load theory) and presenting technical content through hands-on, real-world projects

(Constructivism, cognitivism, adult learning, and situated cognition theories). It also included implementing techniques that promote ease of understanding and emphasise the usefulness of learning (TAM).

The implementation phase subsequently engages the target audience with the OERs and collects empirical data on their comprehension of the instructional content and their intention to apply the knowledge in real-world contexts. This leads to the evaluation phase, which analyses the empirical data to assess goal achievement. These outcomes can also inform improvements to the OERs.

Finally, the use phase follows, wherein the outcomes of the evaluation phase are used to generate insights for future applications and develop solutions to similar problems. The interrelationship between the phases of OER-PattEdu is illustrated by the arrows in Figure 3.

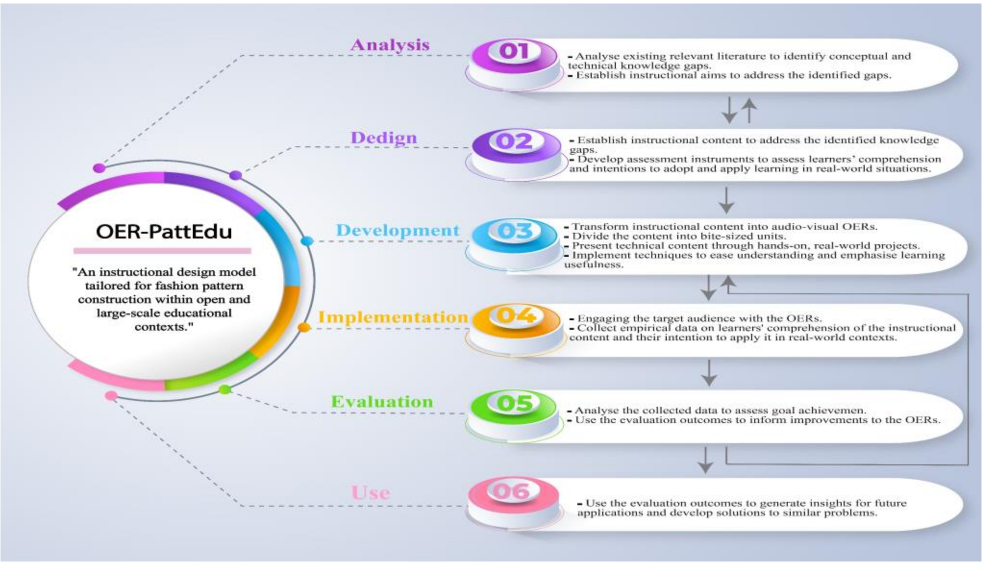

Figure 3 The OER-PattEdu IDM

4. OUTCOMES

The developmental methodology resulted in the creation of the OER-PattEdu IDM (Figure 3). This is an OER-oriented IDM that integrates OERs and open LMSs, grounded in pattern construction learning theories, human learning theories, higher education theories, open online asynchronous learning, and technology adoption theories. The model aims to facilitate the efficient and sustainable dissemination of pattern construction innovations at a large scale within both the fashion industry and academia.

V. CONCLUSION, CONTRIBUTIONS AND IMPLICATIONS

Advances in pattern construction technologies continuously introduce superior approaches to existing methods in terms of sustainability, efficiency, and effectiveness. However, the methods to disseminate and enhance the adoption of these novel approaches at a large scale within the practitioner's community, both in academia and industry, are yet to be established. Based on a comparative analysis grounded in empirical data from existing research, this study established a method combining OERs and open LMS platforms as a superior, sustainable, efficient, and effective approach to the large-scale dissemination and adoption of emerging pattern construction technologies. This method could serve as a foundation for future research in this area.

To the researchers' knowledge, no previous studies have investigated the domains of pattern construction learning, particularly in the context of pattern construction open education. Drawing on multidisciplinary literature, this study explored this area and identified five key learning domains: motor skills, verbal information, intellectual skills, cognitive strategies, and attitudes, highlighting the effective learning needs of each.

The study also employed behaviourism, cognitivism, constructivism, and TAM to understand the learning mechanisms associated with these domains. This approach is essential in enabling dissemination tools' developers to develop instructional strategies that facilitate effective learning and adoption of novel technologies.

Existing literature has identified challenges in pattern construction learning, yet no solutions have been developed, particularly within the context of open education. This study addressed these challenges by proposing solutions, including the use of a multimedia teaching approach to bridge the gap between teaching methods and learners' diverse learning preferences. It also incorporates microlearning, bite-sized learning, and cognitive load management approaches to reduce the inherent complexity of pattern construction. Also, the study used the hands-on, real-world project learning approach to address the gap between pattern construction theories and practice. This gap hinders the effective comprehension of and engagement with novel technologies, which are the requirements of realising their benefits and thus enhancing their adoption.

The frameworks guiding the development of OERs and their hosting on open LMS platforms to support the dissemination of emerging pattern construction technologies at a large scale have not yet been developed. Therefore, this study extends the literature in this area by developing a model called OER-PattEdu, grounded in the theories and solutions mentioned above to enhance the effective large-scale promotion and adoption of novel technologies within this field.

It is expected that this study will spark further debate regarding the methods of disseminating novel technologies in the field. Developmental researchers may also be motivated to develop more advanced IDMs based on the outcomes of this study. Both developmental researchers and instructional design practitioners in the field could use OER-PattEdu to promote novel technologies at a large scale. By doing so, lifelong learning and professional development in the field would shift towards more efficient, sustainable, and effective paradigms.

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