Personalization in the Context of Blended Learning: Systematic Review of the Literature and Proposal for its Implementation

Personalização no Contexto do *Blended Learning*: Revisão Sistemática da Literatura e Proposta para sua Implementação

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ABSTRACT

From the rise of information and communication technologies (ICTs) in the context of education, modalities such as e-learning (learning supported by ICTs) and blended learning (combination of classroom and online learning) emerge. In this scenario, there is a need to discuss the feasibility and implementation of personalized educational processes according to the needs and characteristics of students. Thus, the general objective of this work was to identify the steps that must be followed for the personalization of educational processes in the context of blended learning. For this to be possible, a systematic literature review was conducted and, based on the results obtained, a framework for personalizing education in virtual learning environments (VLEs) is proposed. The proposed structure consists of three modules in the VLE – concerning student, knowledge, and personalization –, expected to assist teachers and educational institutions in implementing this trend in virtual teaching.
Keywords: blended learning, personalization, customization, framework, systematic literature review.

RESUMO

A partir da inserção das tecnologias da informação e comunicação (TICs) no contexto da educação surgem modalidades como o *e-learning* (aprendizado apoiado nas TICs) e o *blended learning* (combinação de aprendizado presencial e online). Nesse cenário, uma necessidade latente é a discussão acerca da viabilização e da implementação de processos educativos personalizados conforme as necessidades e características dos estudantes. Assim, o objetivo geral deste trabalho foi identificar as etapas que devem ser seguidas para a personalização de processos educativos no contexto do *blended learning*. Para que isso fosse possível, valeu-se de uma revisão sistemática da literatura e, com base nos resultados obtidos, propõe-se um *framework* a ser utilizado para a personalização

Received on: 02/04/2024
Approved on: 09/04/2025

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RESUMO

da educação em ambientes virtuais de aprendizagem (AVAs). A estrutura proposta consiste em três módulos no AVA – do estudante, do conhecimento e da personalização –, sendo capaz de auxiliar docentes e instituições de ensino na implementação dessa tendência no ensino virtual.
Palavras-chave: ensino híbrido, personalização, customização, estrutura, revisão sistemática da literatura.

Introduction

In recent years, new research in the field of education has increasingly focused on the use of the Internet and information technology to promote online learning, overcoming many barriers of traditional education such as space, time, quantity, and scope (Maraza-quispe et al., 2019). In this context, the term e-learning has emerged, which, in a simple yet objective definition, can be understood as learning supported by information and communication technologies (ICTs) (Deerajviset & Harbon, 2014), integrating these technologies into teaching and learning processes. Among its main contributions is the increased flexibility of time and space compared to the traditional classroom (Wu et al., 2017).

Within the virtual education context, some researchers believe that the most significant impact of online teaching steams from combining traditional face-to-face instruction with online learning to create what is known as blended learning (Hwang & Arbaugh, 2009). This modality aims to integrate in-person and distance activities by leveraging the best of both face-to-face and virtual instruction, thereby enhancing the teaching and learning process in the contemporary educational landscape (Author, 2019).

Online learning systems have been widely adopted; however, they still face major challenges associated with their use, such as low course/activity completion rates among students and limited adaptability regarding learning content (Abhirami & Devi, 2022). One key challenge is recommending high-quality and appropriate learning materials for students to help identify a learning path that facilitates the understanding of specific content (Martin & Dominic, 2019). Nevertheless, most learning that occurs within such environments continues to rely on a homogeneous instructional model, offering on a single set of materials offered to all types of stu-

dents regardless of their cognitive abilities, prior experiences, or learning styles (Xu et al., 2014).

Students differ from one another in various ways, ranging from talents in specific areas of knowledge, prior knowledge of the subject matter, and preferred learning styles to family context, motivation to study, and study habits (Kostolányová et al., 2012). These individual differences have a significant impact on learning outcomes, and providing the same materials and instructions to all students without taking their individualities into account may lead to learning results below their potential (Wu et al., 2017).

An adaptive e-learning system should meet the needs and expectations of each learner (Martin & Dominic, 2019), and be capable of adjusting instructional strategies and study materials according to student characteristics such as learning style, motivation, personality, and knowledge of the subject matter (Alshammari & Qtaish, 2019). Such systems allow for personalized learning experiences and, consequently, maintain student engagement throughout different activities and learning stages—a key factor for the success of learning management systems (LMSs) (Abhirami & Devi, 2022).

Thus, the research problem addressed in this study is as follows: What steps should be followed to personalize educational processes within the context of blended learning?

A systematic literature review (SLR) was chosen as the methodological approach for this investigation because it enables the systematic collection and evaluation of evidence related to a specific topic (Biolchini et al., 2005) and allows for the interpretation of relevant content derived from studies on a particular subject, area, or phenomenon of interest (Kitchenham, 2004). The general objective of this study is to identify the steps that should be followed to personalize educational processes within the context of blended learning. To achieve this, two specific objectives were defined: (1) to identify, through an SLR, the stages or procedures that characterize the personalization of educational processes in the blended learning context, and (2) to propose, through a framework, a logical sequence of steps to be followed for the personalization of educational processes within this context.

The theoretical contribution of this article lies in the systematization and conceptual structuring of the stages required for the personalization of educational pro-

cesses in the blended learning context, based on evidence extracted from recent scientific literature. By proposing a structured framework grounded in empirical and theoretical studies, this work enhances the understanding of the elements that comprise personalized learning in hybrid environments. Therefore, it represents a contribution that can support future investigations and practical applications in the field of technology-mediated education, particularly in the development of more adaptive and learner-centered systems and pedagogical strategies.

This paper is divided into five sections, beginning with this introduction. The second section presents the steps followed in the development of the study. The third describes the results obtained from the conducted SLR and the proposed framework for personalizing/customizing educational processes in the context of blended learning. Finally, the last section discusses the conclusions, limitations, and directions for future research.

Research Method

The systematic literature review (SLR) is divided into three phases, planning, executing, and reporting, according to Kitchenham (2004) and Author (2021). This section aims to outline the foundational procedures followed in conducting the proposed SLR, as well as to detail the steps carried out during its planning and implementation.

PHASES OF A SYSTEMATIC LITERATURE REVIEW

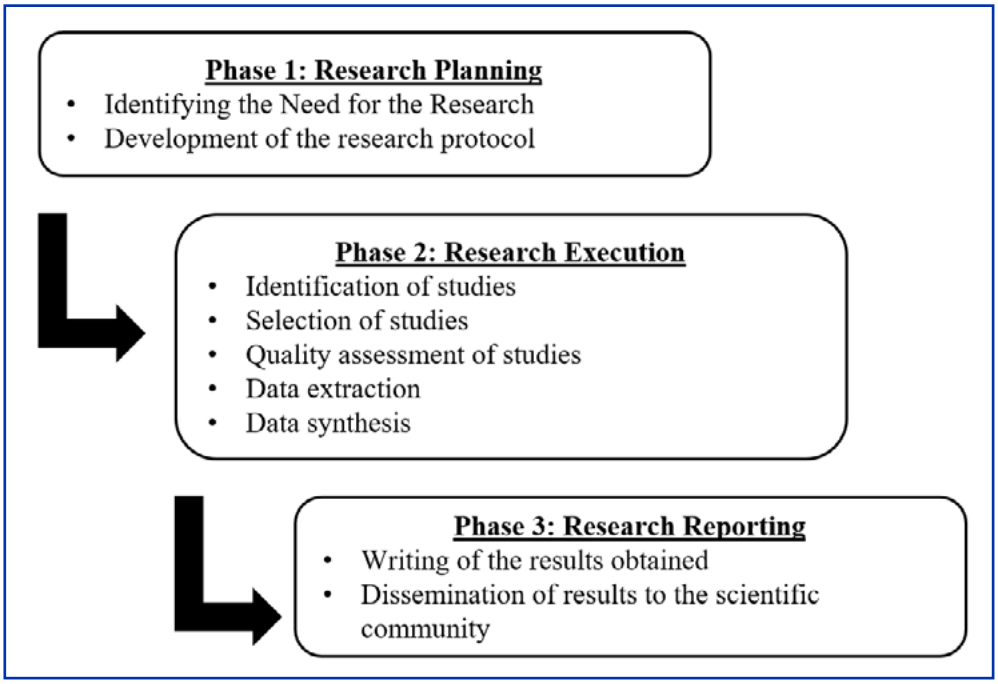
The first phase of conducting an SLR, known as the planning phase, involves identifying a research need and developing a research protocol that provides a detailed description of the steps to be followed (Author, 2021; Kitchenham, 2004).

The subsequent phase, known as the conducting phase, is the stage in which the actual execution of the research takes place, following the definitions established in the research protocol (Biolchini et al., 2005). This phase includes all steps from identifying and selecting studies to assessing their quality and synthesizing the data found (Kitchenham, 2004).

The reporting phase, which is the final stage of the SLR, consists of presenting the results obtained in the form of a technical report, thesis, or scientific pub-

lication (Kitchenham, 2004). Figure 1 illustrates the phases and stages of an SLR according to Author (2021), which served as a reference for conducting this study. Each of these phases is described below in line with the literature and the procedures in this research.

Figure 1. Phases and Stages of a Systematic Literature Review (SLR).



Source: Celestino e Viana (2021).

RESEARCH PLANNING

The planning phase, the first stage of an SLR, consists ofof two steps: (1) identifying the need for a systematic review and (2) developing a research protocol (Author, 2021; Kitchenham, 2004).

Identifying the Need for the Research

The need to conduct a systematic review arises from the demand to summarize all available information on a given topic or phenomenon in an unbiased manner,

in order to draw conclusions from individual studies or even to identify directions for future research (Kitchenham, 2004).

In virtually all sectors of modern society, the prevailing keyword is "change"—with technological change being the most evident, as it significantly alters the way people work, study, and interact (Rocha, 2021). ICTs are one of the main drivers of these societal changes, and education—particularly higher education—is no exception (Garrison & Kanuka, 2004).

In recent decades, many companies have focused on understanding consumer needs and, consequently, to creating personalized products and services (Royer & Santos, 2010), regardless of their field of operation (Pancotto et al., 2016). The personalization of a product or service refers toits adaptation to a customer's specific needs (Andrade, 2016), whether through the inclusion or modification of elements (Gomes et al., 2012), thereby adding value to the consumer's perception (Andrade, 2016).

Beese (2019, p. 254) observes that there is no consensus regarding the term "personalization" in the educational context and broadly defines it as "any process that uses information from or about a student to generate plans or decisions for that student."

A company's competitive advantage grows with its ability to meet customers' specific desires concerning a product or service (Royer & Santos, 2010). The educational field is no exception: the ability to identify students' needs and personalize offerings may lead to greater satisfaction (Porto et al., 2011), particularly in a context where higher education institutions face growing demands from students for enhanced teaching and learning experiences (Garrison & Kanuka, 2004).

As electronic learning expands, so does the possibility of personalizing education—offering individualized responses to learners' needs—through content-presentation tools available in virtual learning environments (VLEs) (Gomes et al., 2012). Despite the potential of learning management systems (LMSs), these systems currently offer the same learning objects to all students, regardless of their learning styles (Martin & Dominic, 2019).

When seeking personalization to meet individual learner needs, it is important to consider the various approaches to the teaching and learning process. In this context, understanding the differences among pedagogy, andragogy, and heutago-

gy (Anastácio & Ronqui, 2023) emerges as an essential foundation for building more effective and inclusive educational practices.

Pedagogy refers to teaching children, adopting a teacher-centered approach in which the instructor defines the content, methods, and pace of learning (Araújo et al., 2021). The main objective is the transmission of fundamental knowledge for the learner's early development. The teacher assumes the role of authority and guide, leading the learning process—a model traditionally applied in formal school settings such as primary and secondary education (Coelho et al., 2021).

In contrast, andragogy refers toadult education, recognizing that adult learners possess significant prior experiences and prefer self-directed learning (Knowles, 1980). The andragogical model emphasizes learning based on real-world problems and the practical application of knowledge (Coelho et al., 2021). The goal is to facilitate the acquisition of skills and competencies that meet adults' immediate needs. Here, the teacher acts as a facilitator or mentor, fostering a collaborative and participatory learning environment. Andragogy is frequently applied in contexts such as adult education, corporate training, and continuing education programs (Araújo et al., 2021).

Heutagogy, in turn, proposes a self-directed learning model in which the learner is primarily responsible for their own learning process (Hase & Kenyon, 2000). This model emphasizes learner autonomy in setting goals, choosing methods, and evaluating progress. Its objective is to develop the ability to "learn how to learn", promoting critical thinking and complex problem-solving skills (Coelho et al., 2021). In heutagogical environments, the teacher acts as a mentor, supporting learners in constructing knowledge independently. Heutagogy is particularly effective in online and distance learning environments, where learners can manage their own pace and learning styles (Araújo et al., 2021).

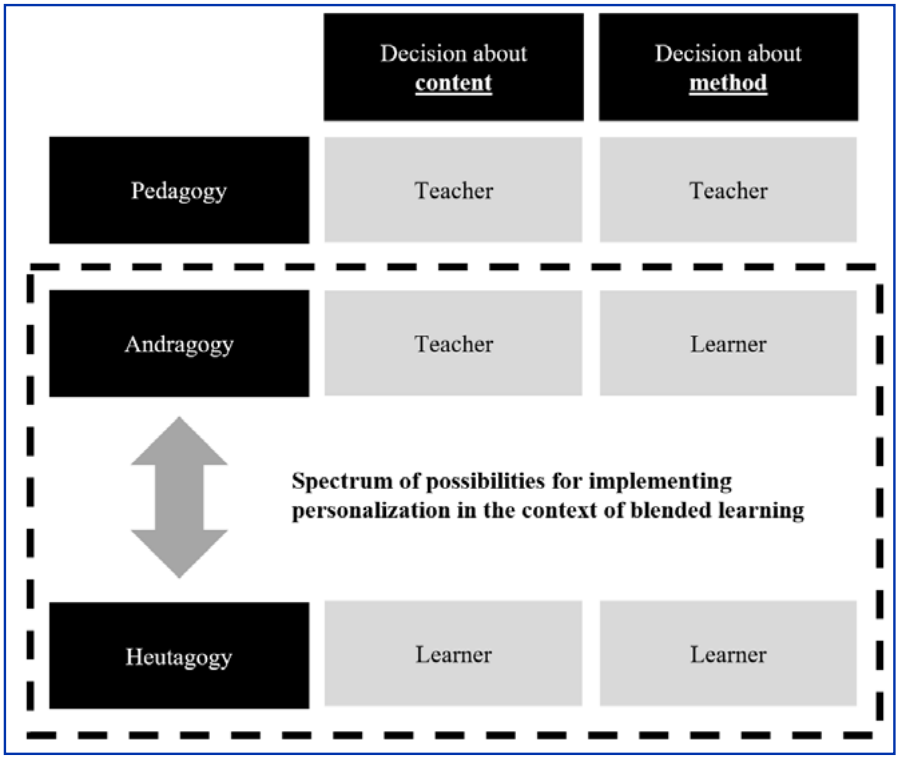
Although distinct, these educational approaches can be integrated and adapted according to learners' specific characteristics and learning contexts. The choice among pedagogy, andragogy, and heutagogy should consider factors such as learners' age group, prior experience, learning objectives, and educational setting (Coelho et al., 2021; Hase & Kenyon, 2000).

In pedagogy, knowledge transmission occurs vertically—the teacher is positioned at the top, responsible for imparting knowledge into students without consid-

ering their needs or interests (Maia Neto et al., 2023). In andragogy, since it addresses a different audience, the teacher's role must shift—from being the sole holder of information to taking part in decision-making regarding teaching, planning, content, assessment, and methodology (Coelho et al., 2016). Finally, in heutagogy, teachers cease to be information transmitters and become facilitators of the learning process. This model aims to develop learners' autonomy and self-direction, making them responsible for their educational journey (Lopes, 2023).

At this point, an important aspect related to personalization emerges—it can be applied both in andragogical and heutagogical contexts, as shown in Figure 2, where the decision over the learning journey may lie with either the teacher or the learner.

Figure 2. Spectrum of the Personalization of Educational Processes, Including in the Context of Blended Learning



Source: Prepared by the authors based on Araújo et al. (2021), Coelho et al. (2016), Lopes (2023), Maia Neto et al. (2023), and Marques and Duarte (2021).

Heutagogy was introduced in higher education through the development of information technology, transforming the teacher into a tutor who makes available learning resources, while the learner is responsible for planning their own path (Marques & Duarte, 2021). The heutagogical model is closely associated with communication technologies—particularly those used in online education—characterized by high levels of learner autonomy. As a relatively recent field of study, it offers fertile ground for further research (Coelho et al., 2016). Table 1 presents a comparative overview of key aspects of pedagogy, andragogy, heutagogy, and personalized learning, as previously discussed.

Table 1. Main aspects of pedagogy, andragogy, heutagogy, and personalized learning.

Aspects	Pedagogy	Andragogy	Heutagogy	Personalized Learning
Definition	Traditional teacher-centered approach, in which the instructor guides and directs students' learning.	Focus on the specific needs of adult learners, highlighting the importance of autonomy and prior experiences.	Approach that places the learner as the main protagonist, allowing them to lead their own learning process.	Approach that seeks to adapt the learning process according to individual students' needs.
Focus	Emphasizes knowledge transmission by the teacher, following a predetermined curriculum.	Active involvement of adults in setting goals, combining their experiences with the proposed curriculum.	Characterized by significant learner autonomy in defining objectives, methods, and learning pace.	Strategy centered on the learning process or adaptive e-learning systems.
Process	The teacher plays a central role in directing instruction, following a predetermined curriculum.	Strategies that acknowledge adult autonomy, integrating their experiences and interests into the educational process.	The learner takes responsibility for managing their own learning, making decisions about what, how, and when to learn.	Content is adjusted based on characteristics such as learning style, motivation, personality, and prior knowledge.

Responsibility	The teacher is responsible for delivering knowledge and assessing students.	Adults take a more active role in their own learning, collaborating with the educator in setting goals and strategies.	The teacher acts as a facilitator or tutor, providing resources, but the learner is primarily responsible for their learning journey.	Personalization is implemented by the teacher or system, focusing on adapting material according to student profiles.
Challenges	Resistance to curricular flexibility and the incorporation of non-traditional methods.	Challenges in transitioning from more directive approaches to environments that promote adult learner autonomy and self-regulation.	Need to develop self-directed learning and self-regulation skills among learners.	Difficulties in providing truly personalized content for different learning styles.

Source: Prepared by the authors.

E-learning systems should provide an innovative alternative to traditional classrooms by personalizing the needs of the various actors (students, tutors, and teachers) throughout the teaching and learning process (Martin & Dominic, 2019).

However, current studies on e-learning remain insufficient to address the problem of using the same materials and strategies for students with different learning styles, as is done in traditional systems (Blagoev et al., 2021). Therefore, further research on adaptive systems in the e-learning context is therefore needed (Alameen & Dhupia, 2019), as current systems still struggle to offer personalized, learner-centered content (Premlatha et al., 2016). In this sense, the creation of learner-based content tailored to individual characteristics has been a major pursuit among learning environment designers (Labib et al., 2017).

Given this context, the guiding question for the proposed SLR was formulated as follows: What aspects characterize the personalization of educational processes within the blended learning model? Based on this guiding question, the research protocol was structured with the objective of gathering evidence and information to identify and consolidate possible answers and conclusions.

Research Protocol

According to Kitchenham (2004), the research protocol specifies the methods to be used in the SLR, including the questions the review intends to answer, the strategies to locate primary studies, the procedures for study selection, the criteria for quality assessment, and the strategies for data extraction and synthesis. This section focuses on presenting all the strategies defined for this purpose.

Three databases were chosen for conducting the SLR: Elsevier (ScienceDirect), Web of Science, and Scopus. These were selected because they are international databases encompassing a wide range of journals and academic fields.

Kitchenham (2004) recommends conducting an exploratory search to assist researchers in selecting appropriate terms for building the SLR search strings. This exploratory search was carried out in four databases (Web of Science, Scopus, ScienceDirect, and Google Scholar) by combining the following terms: personalized, customized, and individualized with learning, education, blended learning, and e-learning. Although the focus of this study is on the blended learning modality, the term e-learning was included to broaden the scope and identify potentially relevant practices for the teaching and learning process.

Following the exploratory search, six concepts were defined based on the research question and objectives of the intended systematic review. Concepts 1 through 5 refer to the variety of terms used to describe—sometimes imprecisely—the personalization of educational processes. For the purposes of this SLR, the content and implementation methods of personalization are more relevant than the specific term used; hence, this variety was deemed acceptable. Concept 6 represents the application scope of personalization, limited to blended learning and e-learning modalities, with a focus on VLEs—particularly Moodle. Table 2 presents the investigated concepts and their synonyms.

Table 2: Concepts and their synonyms to be searched in the search strings.

Concept	Terms
Nº 1	*Adaptive learning e adaptive education*
Nº 2	*Personalized learning e personalized education*
Nº 3	*Customized learning e customized education*

Nº 4	*Individualized learning e individualized education*
Nº 5	*Differentiated learning e differentiated education*
Nº 6	*Blended learning, b-learning, elearning, e-learning, moodle e learning management system*

Source: Prepared by the authors.

The combination of these defined concepts led to the creation of the search strings used in the advanced search mechanisms of the selected databases. Table 3 presents the relationship between the defined concepts and the corresponding search strings. A higher number of shorter strings were used, each containing fewer Boolean connectors, due to the limitation of eight connectors in one of the selected databases.

Table 3. Relationship between concepts and search strings.

String	Concepts
Nº 1	1 + 6
Nº 2	2 + 6
Nº 3	3 + 6
Nº 4	4 + 6
Nº 5	5 + 6

Source: Prepared by the authors.

The search strings used in the advanced search mechanisms (title, keywords, and abstract) of the databases are presented in Table 4.

Table 4. Search strings to be used.

String 1	((“adaptive learning”) OR (“adaptive education”)) AND ((“elearning”) OR (“e-learning”) OR (“blended learning”) OR (“b-learning”) OR (“moodle”) OR (“learning management system”))
String 2	((“personalized learning”) OR (“personalized education”)) AND ((“elearning”) OR (“e-learning”) OR (“blended learning”) OR (“b-learning”) OR (“moodle”) OR (“learning management system”))

String 3	((“customized learning”) OR (“customized education”)) AND ((“elearning”) OR (“e-learning”) OR (“blended learning”) OR (“b-learning”) OR (“moodle”) OR (“learning management system”))
String 4	((“individualized learning”) OR (“individualized education”)) AND ((“elearning”) OR (“e-learning”) OR (“blended learning”) OR (“b-learning”) OR (“moodle”) OR (“learning management system”))
String 5	((“differentiated learning”) OR (“differentiated education”)) AND ((“elearning”) OR (“e-learning”) OR (“blended learning”) OR (“b-learning”) OR (“moodle”) OR (“learning management system”))

Source: Prepared by the authors.

After conducting the searches using the created strings, it was necessary to identify studies that aligned with the objectives of the proposed SLR. For this purpose, a set of inclusion and exclusion criteria were established (Author, 2021), as shown in Table 5.

Table 5. Inclusion and exclusion criteria for the obtained results.

Inclusion Criteria (IC)
IC1 – Studies published in the format of a scientific article.
IC2 – Studies published in English or Portuguese.
IC3 – Scientific articles presenting practical or theoretical contributions related to the personalization of educational processes considering blended learning and e-learning.
IC4 – Scientific articles available in full text and open access.
Exclusion Criteria (EC)
EC1 – Scientific articles published in languages other than English or Portuguese.
EC2 – Other literature presented in formats different from scientific articles.
EC3 – Duplicate scientific articles.
EC4 – Scientific articles that do not present practical or theoretical contributions related to the personalization of educational processes considering blended learning and e-learning.
EC5 – Scientific articles from secondary or tertiary research.
EC6 – Scientific articles that do not meet more than 50% of the quality criteria.

Source: Prepared by the authors.

The defined quality assessment criteria are presented in Table 6. The first two criteria evaluate the alignment of each study with the objectives of the proposed SLR. The third verifies whether the proposed model (when applicable) was experimentally validated. The fourth assesses whether the strategies for personalizing learning materials are presented. Finally, the last two criteria measure the academic impact of the work.

Table 6. Study evaluation criteria.

Evaluation Criteria (EvC)	Score
EvC1 – Does the study present practical or theoretical contributions related to the personalization of educational processes considering blended learning and e-learning?	Yes: 1; No: 0.
EvC2 – Does the study provide a framework (or model) to be followed for the personalization of educational processes in the context of blended learning and e-learning?	Yes: 1; No: 0; Partially: 0,5.
EvC3 – Is the proposed framework (or model) validated based on students' perceptions?	Yes: 1; No: 0.
EvC4 – Does the study present ways to personalize content, materials, lessons, assessments, and other elements related to the context of blended learning and e-learning?	Yes: 1; No: 0; Partially: 0,5.
EvC5 – Does the study has citations?	Yes: 0,5; No: 0.
EvC6 – Is the study published in sources that provide quality indicators (h-index or JCR)?	Yes: 0,5; No: 0.

Source: Prepared by the authors.

Studies that met these criteria were considered eligible for full reading and subsequent analysis.

RESEARCH EXECUTION

The second phase of an SLR, the research execution, consists of five steps: (1) study identification; (2) selection of primary studies; (3) quality assessment; (4) data extraction; and (5) data synthesis (Kitchenham, 2004).

The first step involved conducting the actual search using the predefined strings in the selected databases, restricted to the fields "title", "abstract", and "keywords". This search was conducted on March 24, 2022, applying inclusion criteria 1, 2, and 4, and exclusion criteria 1 and 2, as these filters are available in the advanced search options of the chosen databases. Table 7 presents the databases, the search strings used, and the results obtained.

Table 7. Information on the search conducted and the results obtained.

Database	*Search string*	Results	Results after IC1, IC2, IC4, EC1, and EC2
Web of Science	1	562	47
Web of Science	2	538	53
Web of Science	3	50	5
Web of Science	4	66	7
Web of Science	5	11	3
Scopus	1	1.324	132
Scopus	2	1.214	106
Scopus	3	104	12
Scopus	4	167	16
Scopus	5	27	6
Science Direct	1	55	1
Science Direct	2	62	11
Science Direct	3	4	1
Science Direct	4	5	3
Science Direct	5	0	0
Total	4.189	403	403

Source: Prepared by the authors.

The searches returned a total of 4,189 studies. Across all databases, filters were applied for document type: scientific article, open access, and languages: Portuguese and English (using inclusion criteria 1, 2, 4, and 5 and exclusion criteria 1 and 2), resulting in 403 studies.

Subsequently, CSV files containing article identification information (title, authors, publication year, etc.) were exported from the Web of Science and Sco-

pus databases. As ScienceDirect does not provide a CSV export option, the data extraction was performed manually. The list of article titles, corresponding search strings, and database sources was compiled in a Microsoft Excel 2016 spreadsheet.

The first step in data processing involved removing duplicate records (exclusion criterion 3), which eliminated 128 studies. Next, the article titles were screened (as full-text reading was not feasible), applying inclusion criteria 1, 2, and 3. This step resulted in the selection 135 selected articles and the exclusion of 140.

The next stage involved reviewing the abstracts of the selected articles to more carefully assess their alignment with the research objectives. Again, inclusion criteria 1, 2, and 3 and exclusion criteria 1 and 2 were applied, resulting in 74 selected and 61 excluded studies. Finally, the quality of the 74 studies was assessed using the predefined evaluation criteria, leading to the rejection of 50 studies and yielding a final sample of 24 articles.

RESEARCH REPORTING

According to Kitchenham (2004), the final stage of an SLR consists of communicating the achieved results, generally in two formats: (1) as a technical report or part of a thesis, or (2) as a journal publication. Therefore, the present article serves as the report of the conducted SLR.

Results

This section initially presents the results obtained from the systematic literature review (SLR) regarding the aspects that characterize the personalization of educational processes within the blended learning and e-learning models. Subsequently, it outlines a proposed framework to guide the personalization of educational processes in the context of blended learning.

ASPECTS OF THE PERSONALIZATION OF EDUCATIONAL PROCESSES IN THE BLENDED LEARNING AND E-LEARNING MODELS

Through the analysis of the final sample obtained from the procedures of the conducted SLR, it was possible to identify that the studies addressing the person-

alization of educational processes in e-learning or blended learning environments presented their approaches in the form of systems. These systems, in turn, featured modules composed of technological processes and mechanisms aimed at offering students instructions and materials tailored to their individual conditions. Table 8 lists the modules cited by the respective studies in the sample.

Table 8. Modules cited during the personalization process.

Authors (vertical)/ Module (horizontal)	Student	Instructor	Knowledge	Personalization
Abhirami e Devi (2022)	X	X		
Al-Khanjari e Al-Kindi (2021)	X			X
Blagoev et al. (2021)	X		X	X
Fazazi et al. (2021)	X		X	X
Martin et al. (2021)	X			X
Alameen e Dhupia (2019)	X	X		X
Alshammari e Qtaish (2019)	X		X	X
Martin e Dominic (2019)	X		X	X
Maraza-Quispe et al. (2019)	X	X	X	X
Murad e Yang (2018)	X		X	X
Wu et al. (2017)	X		X	X
Chang e Chen (2016)	X			X
Gasparinatou e Grigoriadou (2015)	X	X		X
Kostolányová et al. (2012)	X	X		X

Source: Prepared by the authors.

The names of the modules were standardized in Table 8, since, although some studies used different names, their descriptions and functionalities were found to be similar.

Student/Learner Module

The main objective behind personalization in e-learning environments is to create learning materials tailored to students' specific characteristics, enabling

them to learn more effectively and efficiently (Labib et al., 2017), a practice that has become increasingly popular in the field of education (Chang & Chen, 2016; Wu et al., 2017).

The learner module stores information and data about students (Abhirami & Devi, 2022; Alshammari & Qtaish, 2019; Kostolányová et al., 2012; Wu et al., 2017) and their interactions with the learning system/environment (Alameen & Dhupia, 2019) including the selected learning sequence and the time spent on materials and proposed activities (Gasparinatou & Grigoriadou, 2015). Based on the results achieved by each learner, the information is continuously updated (Blagoev et al., 2021).

Some of the student information stored includes learning history, progress within the current learning object, and learning style (Fazazi et al., 2021). Demographic data (Alameen & Dhupia, 2019) and the student's level of knowledge about the subjects to be studied are also considered (Alameen & Dhupia, 2019; Alshammari & Qtaish, 2019; Blagoev et al., 2021; Gasparinatou & Grigoriadou, 2015; Murad & Yang, 2018), which help determine the learner's skill or competence level (Wu et al., 2017) and significantly impact knowledge acquisition (Blagoev et al., 2021).

The measurement of students' knowledge level can be carried out through questionnaires (Alameen & Dhupia, 2019) or pretests (Alshammari & Qtaish, 2019). Celestino and Viana (2021) suggest varying the materials offered to students according to their knowledge level on the topic being studied (Blagoev et al., 2021; Gasparinatou & Grigoriadou, 2015), with the goal of developing an optimized and faster learning path for each student, thereby reducing the time needed for knowledge accumulation and increasing motivation to complete the course (Blagoev et al., 2021).

A student's learning style is a unique characteristic that contributes to learning success by providing details about how the learner best acquires knowledge (Abhirami & Devi, 2022; Martin & Dominic, 2019). It describes preferred ways of perceiving, processing, and retaining information during the learning process (Labib et al., 2017; Martin et al., 2021) and is often regarded as the most important information to obtain from students (Kostolányová et al., 2012; Labib et al., 2017; Zhang et al., 2020). Other studies also mention the identification of students' learning styles within this module (Abhirami & Devi, 2022; Alameen & Dhupia, 2019;

Alshammari & Qtaish, 2019; Gasparinatou & Grigoriadou, 2015; Maraza-Quispe et al., 2019), which can be obtained through questionnaires (Alameen & Dhupia, 2019; Maraza-Quispe et al., 2019; Martin & Dominic, 2019) or through the analysis of student behavior within the learning system (Martin & Dominic, 2019; Martin et al., 2021).

Regarding the discussion of learning styles—further explored in the section about the Knowledge Module—this study focuses on the Felder-Silverman model, as it was the most frequently cited model in the analyzed sample. It is also suitable for web-based learning environments (Zhang et al., 2020), commonly used in online contexts (Alshammari & Qtaish, 2019), and has already demonstrated reliability and validity (Limongelli et al., 2009).

Instructor/Tutor Module

The instructor (or tutor) module provides reports containing information about students' progress, feedback received, and completed learning activities (Alameen & Dhupia, 2019). It also stores the instructional content to be taught in multiple formats that vary according to students' learning styles (Kostolányová et al., 2012). Moreover, it encompasses the teaching and learning strategies adopted in the course design, as well as the definition of instructional strategies according to the learner's learning style (Maraza-Quispe et al., 2019). This information should be used by instructors to make potential adjustments to the course strategy (Alameen & Dhupia, 2019).

Within this module, the tutor also develops and uploads learning materials, presenting the content, activities, expected responses, and feedback system (Gasparinatou & Grigoriadou, 2015). The creation of personalized content in e-learning environments is an intensive process that uses a variety of resources requiring considerable time and technological expertise (Blagoev et al., 2021).

Knowledge/Content Module

The knowledge (or content) module stores the learning materials to be taught (Alshammari & Qtaish, 2019; Wu et al., 2017), distributed in a way that covers different learning styles and a wide range of media formats (Blagoev et al., 2021),

thus enabling personalization in the adaptive e-learning system (Alshammari & Qtaish, 2019).

According to Martin and Dominic (2019), this module consists of the learning content required for the course or curriculum, structured hierarchically in three layers. The first layer refers to the course, which is divided into several chapters; each chapter consists of a set of concepts, and each concept is mapped to different learning objects.

Learning objects, in turn, are components presented in various formats (e.g., lecture notes, audio, video, graphics, images, animations, PDFs, and PPTs) (Martin & Dominic, 2019). These objects must include metadata such as difficulty level, authorship, creation date, keywords, and format (Fazazi et al., 2021). The teaching materials are influenced by the learning styles considered in the model and serve as the link between the content and the learner's learning style (Maraza-Quispe et al., 2019)

Abhirami and Devi (2022) discuss the most appropriate type of activity for each of the eight learning styles described in the Felder-Silverman model. This model is based on learners' individual cognitive characteristics and combines four dimensions: processing, perception, input, and understanding of information (Zhang et al., 2020). Regarding these dimensions and their possible classifications, Alshammari and Qtaish (2019) explain:

- Processing: details the techniques learners use to process information, classifying them as active or reflective;
- Perception: refers to preferred types of information, dividing learners into sensing and intuitive;
- Input: concerns the presentation of information, distinguishing learners as visual or verbal;
- Understanding: addresses the preferred structure of information, categorizing learners as sequential or global.

Table 9 provides information related to each of these learning styles. Typically, individuals possess more than one learning style, reflecting a combination of characteristics that can be observed in their personalities (Labib et al., 2017).

Table 9. Learning styles according to the Felder–Silverman model and their descriptions/preferencess.

Style	Descriptions/preferences
Active	They tend to improve their learning efficiency through the active use of study materials. They enjoy communicating with others and completing tasks or solving problems through teamwork. They learn through interaction or by manipulating something, as well as through communication with others.
Reflexive	They are inclined to think and rethink independently. They prefer to complete tasks and solve problems on their own, thinking before acting.
Sensing	They tend to focus on practical cases or specific materials and prefer to solve problems using standardized approaches. Concrete learning resources are more beneficial for them.
Intuitive	They show a preference for abstract materials, as these help them understand the concept being studied. They are good at identifying internal relationships, are creative, and enjoy solving problems in innovative ways.
Verbal	They excel at acquiring detailed information through written or spoken explanations.
Visual	They prefer to obtain information through images, videos, charts, and diagrams.
Sequential	They prefer to study in a logical and sequential order, with each stage of learning clearly defined. They like to focus on small, incremental portions of material.
Global	They prefer to grasp the overall structure and summary of information before delving into specific points and details.

Source: Prepared by the authors based on Abhirami e Devi (2022), Alshammari e Qtaish (2019) e Zhang et al. (2020).

Personalization Module

For adapting e-learning systems, two main possibilities exist: using student information (such as learning style and preferences) or analyzing students' behavioral data during their interactions with the system (Alameen & Dhupia, 2019).

The personalization module draws upon information from the other three modules to apply rules and deliver relevant and appropriate learning materials to each student (Alshammari & Qtaish, 2019; Blagoev et al., 2021; Chang & Chen, 2016; Kostolányová et al., 2012; Martin & Dominic, 2019; Murad & Yang, 2018), using their learning objectives and individual abilities (Wu et al., 2017) to enhance the learning process (Fazazi et al., 2021).

In some cases, the personalization module has a broader range of functionality, such as analyzing learning patterns, offering adaptive resources, recording activities and learner behavior, assessing proposed activities, and collecting user feedback (Alameen & Dhupia, 2019). However, despite the existence of several adaptive modules in the literature, most remain highly abstract and have never been empirically tested (Tmimi et al., 2019).

Table 10 summarizes and compares the main information related to the modules identified throughout the SLR and discussed so far.

Within a pedagogical approach, personalization can be integrated by adapting content and teaching strategies according to students' individual characteristics. This includes identifying learning styles, interests, and skill levels to tailor instructional materials. Moreover, incorporating interactive methods—such as hands-on activities and discussions—encourages active learner participation. The use of formative assessments helps monitor individual progress and allows for continuous adjustments, making the learning environment more inclusive and responsive.

In andragogy, personalization is essential for addressing the specific needs of adult learners. The curriculum can be made flexible, enabling adults to participate actively in defining learning goals and methods. Facilitating the connection between learners' prior experiences and new content strengthens learning relevance. Approaches such as problem-based learning and collaborative projects promote autonomy and self-reflection. Evaluations that recognize the diversity of adult learners' skills and experiences contribute to more effective and inclusive educational practices.

Finally, within a heutagogical approach, personalization reaches its highest level, combining personalized learning paths with learner autonomy. Students take charge of defining their learning goals, methods, and pace, while educators act as mentors, providing resources and guidance as needed. Technological tools and virtual learning environments (VLEs) can be leveraged to give learners greater control

Table 10. Comparative summary among the modules identified in the conducted SLR.

Dimensions	Student or Learner Module	Teacher, Tutor, or Instructor Module	Knowledge or Content Module	Personalization Module
Main Objective	– Personalize learning according to the specific characteristics of students. – Store information about the learner and their interactions with the system.	– Provide reports on student progress and received feedback. – Store instructional information in various formats. – Develop teaching strategies based on learning styles.	– Store the content to be taught. – Distribute materials that encompass different learning styles and media. – Structure knowledge into courses and learning units.	– Use information from other modules to apply rules and provide relevant and appropriate learning materials.
Stored Information	– Student data, access behavior to learning objects. – Learning history, progress, learning style, demographic information.	– Reports on student progress, feedback, and completed activities. – Instructional information in multiple formats. – Teaching strategies and e-learning system design.	– Instructional content. – Learning objects in different formats. – Specifications of learning objects.	– Students' learning preferences. – Information about student behavior.
Identification of Learning Style	– Identify students' learning styles through questionnaires or behavioral analysis.	– Consider students' learning styles in course design.	– Distribute content covering different learning styles. – Consider learning style in content delivery strategies.	– Take students' learning preferences into account to propose corresponding activities.

DOI 10.13058/raep.2025.v26n1.2493
ISSN 2358-0917

Use of Data for Personalization	– Use behavioral and learning style data to update information and personalize learning paths.	Use information on progress, feedback, and learning styles to adjust course strategies.	– Use learning style data to personalize the adaptive e-learning system.	– Use information from other modules to apply rules and deliver personalized materials.
Methods for Identifying Learning Style	– Questionnaires, analysis of student behavior within the system.	– Felder–Silverman model.	– Felder–Silverman model.	– Students' learning preferences.
Findings from Related Studies	–– Learning outcomes improved when both knowledge level and learning style were considered. – Use of questionnaires and behavioral analysis to identify learning styles.	– Personalization based on knowledge level and learning style improved learning effectiveness. – Use of the Felder–Silverman model for personalization.	– Use of the Felder–Silverman model to identify learning styles. – Personalization within the adaptive e-learning context.	– Use of information from other modules to personalize learning. – Emphasis on technological and predictive aspects.

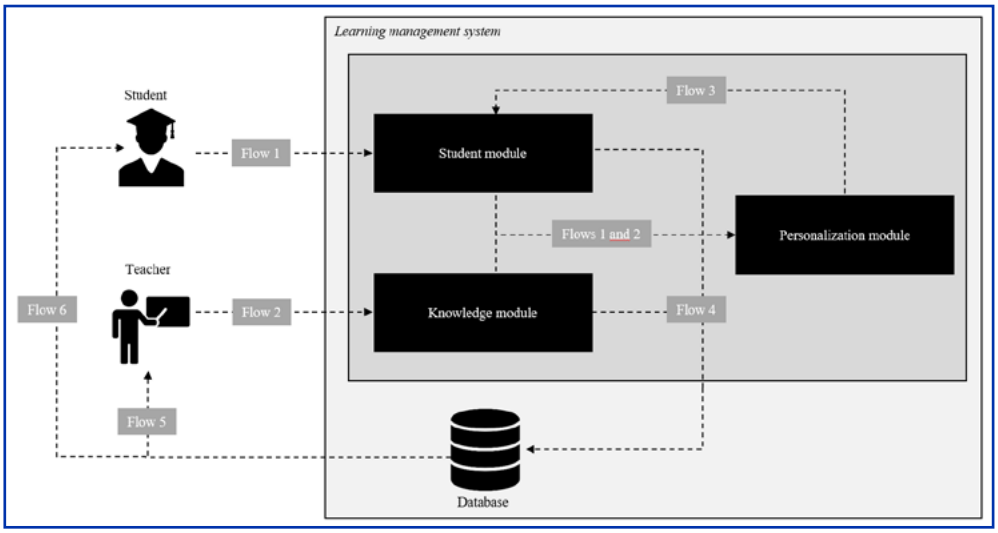
Source: Prepared by the authors.

over their educational journey. Personalization in heutagogy empowers students to become self-determined learners, fostering self-reflection, critical inquiry, and active knowledge construction.

PROPOSED FRAMEWORK FOR THE PERSONALIZATION OF EDUCATIONAL PROCESSES IN THE BLENDED LEARNING MODEL

Following the report of the findings from the systematic literature review (SLR) conducted on the personalization of educational processes in the context of e-learning and blended learning, this section discusses a framework to be used in the design of courses or disciplines in the blended learning modality that aim to offer personalized study materials to students through Learning Management Systems (LMSs). Similar to the studies analyzed, the structure is presented in modules, each with its own functions and processes. Figure 3 illustrates the proposed modules, the information flows among them, and the involved agents.

Figure 3. Modules of the proposed framework.



Source: Prepared by the authors.

The Student Module is responsible for collecting and storing student information, primarily their learning style and knowledge level. The Knowledge Module,

based on instructor inputs, stores the entire structure of the course and includes a matrix capable of linking learning style, knowledge level, and study object to the most suitable learning materials. Finally, the Personalization Module, drawing on information from the other two modules, identifies students' profiles and needs, offering what best fits their learning realities. In addition to these modules, the framework includes the LMS (with a database) and two agents—students and instructors.

Briefly, Flow 1 refers to the initial inputs received by the LMS from students, particularly learning style and knowledge level regarding the subject being studied. Flow 2, similarly, refers to the initial inputs from instructors, containing all course materials provided after course design. Flow 3, using a matrix that relates learning style/knowledge level to study materials, offers each student an individualized learning proposal that best matches their needs. Flow 4 concerns the transfer and storage of information from the three modules to the LMS database. Flow 5 involves information sent to instructors regarding students' interactions with the system—such as content access patterns, behavioral trends, activity feedback, and performance in assessments. These data may be used to make new inputs into the course or materials; in such cases, updates would occur through Flow 2. Finally, Flow 6 refers to the information made available to students as a result of their own interactions, such as grades and feedback from assignments.

Student Module

This module manages direct interaction with students and has four main functions, each related to one of the flows shown in Figure 3:

1. Receiving, through student input, and storing personal information, some of which is required for the personalization process (Flow 1);
2. Displaying personalized content to students through materials received from the Personalization Module (Flow 3);
3. Sending information to the LMS regarding student patterns, behaviors, feedback, and performance (Flow 4);
4. Providing students with information derived from their own interactions with the system, such as activity feedback and assessment grades (Flow 6).

Flow 1 – Information Input

Regarding information collection from students, there are two mandatory data points, one required questionnaire, and a set of optional information depending on the course context and the data instructors intend to analyze for adapting materials or for future improvements.

The mandatory data points are the student's learning style and prior knowledge about the topic to be studied. For learning style, the Felder-Silverman model is recommended because it is widely used in e-learning systems, easy to measure through an online questionnaire, and freely accessible. Prior knowledge should also be gathered through an online questionnaire; however, it is recommended that one questionnaire be applied for each new learning objective rather than a single long one at the beginning of the course.

The required questionnaire should verify several aspects essential for the successful delivery of the blended course: (1) whether the student has internet access capable of supporting multimedia materials and LMS access; (2) whether the student's device meets the minimum hardware and software requirements for accessing the LMS; (3) whether the student has prior experience with the chosen LMS (students without prior experience should receive initial guidance); (4) whether the educational institution provides infrastructure (e.g., computers and internet) for students lacking these resources at home; and (5) the languages understood by the student, to support recommendations of supplementary materials not authored by the instructor.

Additionally, the mandatory questionnaire can be used to collect optional information the instructor deems useful for ongoing or future analyses, such as gender, age, country of origin, educational background, previously completed courses, current degree, course completion percentage, income level, and place of residence.

Flow 3 – Display of Personalized Materials

This flow concerns the ability of the Student Module, in conjunction with the LMS and the Personalization Module, to receive and display personalized study materials to students based on the information collected from them.

Flow 4 – Information Output

This flow involves sending data to the LMS database regarding student behavior—such as system interaction, engagement with learning activities, and use of recommended materials. Macro-level analysis of this data (across all students) can provide insights for instructors to improve or revise the course. The Student Module must be capable of sending this data to the LMS database for proper storage.

Flow 6 – Information Availability

This flow refers to the ability of the Student Module, in conjunction with the LMS database, to provide students with feedback and information about their interactions within the system. The goal is to allow students to monitor their learning progress, view feedback from assignments, and access grades from exercises and assessments.

Knowledge Module

This module is responsible for receiving, through instructor inputs, course information and materials in various formats that support personalization according to student profiles. It performs two main functions, directly linked to the flows illustrated in Figure 3:

1. Receiving, through instructor input, and storing course information and learning materials in different formats necessary for personalization (Flow 2);
2. Sending data to the LMS regarding access patterns, number of views per material, most-visited materials, interaction duration, and student feedback (Flow 4).

Flow 2 – Information Input

Submitting learning materials with appropriate labels (learning style and knowledge level) results from detailed course planning in the blended learning format. The first task for the instructor is to design the Teaching and Learning Plan (TLP), which serves both as a course design tool and as a document informing students about the main aspects of the course. According to Celestino and Viana (2021), the TLP

should include: course identification, syllabus, objectives, program content, methodology, assessment criteria, and references.

Alongside the TLP, the instructor must decide the degree of personalization to be implemented, with two main options.

The first option aligns with andragogical principles, where the instructor selects a specific topic and is responsible for evaluating existing study materials, identifying missing ones, and creating new materials as needed. Personalization occurs through multiple formats of the same content, allowing partial student participation in personalization. However, this approach requires prior validation studies to ensure that material variations based on factors such as learning style and knowledge level effectively enhance learning outcomes. The second option allows for a broader range of content, each topic featuring multiple learning materials suited to various student profiles. Here, the student independently chooses what and how to study, resulting in greater autonomy.

Thus, within the Knowledge Module, the instructor must determine the most suitable approach. Some guiding factors include: the existence of prior studies analyzing the effectiveness of different materials for various learning styles; the availability of sufficient teaching materials to differentiate students based on learning style and knowledge level; and the institutional or curricular context, since some subjects may have mandatory contente.

Once this decision is made, the instructor proceeds to create the learning materials. This step is the core of personalization in the proposed framework, based on learning style and prior knowledge level. It is recommended to consider up to two dimensions of the Felder-Silverman model and two levels of prior knowledge (high and low), resulting in $2^2 \times 2 = 8$ variations per learning material.

The choice of which dimensions to include should depend on: (1) the course's nature and learning objectives; (2) feasibility of creating distinct materials based on the chosen dimensions of the Felder-Silverman model; (3) institutional support for producing multiple versions; and; e (4) existing literature demonstrating the effectiveness of the chosen materials. Table 11 presents the main characteristics of the Felder-Silverman learning style model to guide material development.

Table 11. Learning styles (Felder–Silverman) and characteristics to be considered when designing instructional materials.

Style	Learns best by
Active	Doing ("hands-on"), working in groups, and experimenting or trying things out.
Reflective	Thinking introspectively, working individually, and engaging with theoretical approaches.
Sensing	Memorizing facts, paying attention to details, performing manual tasks, engaging in practical and structured activities that require focus and concrete thinking.
Intuitive	Discovering possibilities and relationships among concepts, innovating, formulating abstract or mathematical representations, and learning new concepts.
Verbal	Reading and listening to explanations, and practicing verbal communication skills.
Visual	Using visual representations and exercising visual–spatial skills.
Sequential	Learning in a linear, step-by-step manner, through sequentially organized explanations.
Global	Through holistic explanations and thinking, establishing connections between parts, and learning by following intuition.

Source: Prepared by the authors based on Labib et al. (2017).

Flow 4 – Information Output

This flow concerns sending data about student access patterns, number of views per material, most-visited materials, interaction duration, and feedback. Macro-level analysis of this information enables instructors to identify areas for improvement or redesign within the course. The Knowledge Module must be capable of transmitting this data to the LMS database for analysis.

Flow 5 – Information Availability

This flow refers to the Knowledge Module's ability, together with the LMS database, to provide instructors with insights into students' interactions with learning

materials. Instructors can thus identify behavioral patterns—such as which materials are most accessed or engagement duration—and use this information to make informed pedagogical decisions.

Personalization Module

The Personalization Module integrates data from the other two modules. On one side are student profiles—composed of learning style and knowledge level; on the other are the learning materials in various formats designed to match these profiles. Its primary function is to provide students with the most suitable materials according to their characteristics (Flow 3).

The Personalization Module mainly consists of settings and parameters configured within the LMS to deliver content according to predefined rules and the chosen personalization model. For example, if a student's learning style in the perception dimension is X and their knowledge level is Y, then the material provided will be Z.

Considerations on the Proposed Framework and Related Literature

The proposed framework for personalization in blended learning aligns with widely recognized theoretical models, such as the Felder-Silverman Learning Style Model (Felder & Silverman, 1988), known for its flexibility in digital environments, and Gagné et al.'s (2005) systematic instructional design principles, which provide structured guidelines for organizing educational experiences. The proposed personalization approach reflects a consolidated trend in the literature advocating for the adaptation of instructional materials to individual learner characteristics.

The modular framework is also consistent with Siemens' (2013) learning personalization approaches, which emphasize technology as a mediator for content adaptation based on learner interactions. Siemens highlights the importance of data analysis in enabling continuous feedback that tailors the learning process to individual needs, fostering a dynamic and responsive environment. Similarly, Anderson (2008) argues that ongoing feedback is crucial for continuously adapting the learning experience, thus enhancing online teaching effectiveness. Anderson also underscores that interaction and sustained support, facilitated by technology, are critical to the success of online learning, ensuring that students feel connected and supported throughout their educational journey.

Finally, the proposed model goes beyond traditional approaches by integrating not only learning style and prior knowledge but also students' interactions with the system. This allows for continuous adjustment and dynamic personalization throughout the course. As discussed by Brusilovsky & Millán (2007), such continuous interaction enables content adaptation not only based on prior knowledge but also in response to learners' choices and actions, creating a more personalized and engaging learning experience.

Conclusions

The current educational landscape, enhanced by ICTs, highlights the need for an approach that goes beyond the mere transposition of classroom content and materials into Virtual Learning Environments (VLEs), especially in e-learning and blended learning modalities. In this context, the personalization of educational materials offered to students emerges as a particularly promising approach. Thus, the guiding question of this research was: What steps should be followed to personalize educational processes in the context of blended learning? To answer this question, the study pursued two specific objectives: (1) to identify, through a Systematic Literature Review (SLR), the stages and procedures that characterize the personalization of educational processes in the context of blended and e-learning; and (2) to propose, through a framework, a logical sequence of steps to be followed for the personalization of educational processes in blended learning environments.

Regarding the first specific objective, the SLR was conducted across three databases using five search strings, resulting in a final sample of 24 articles. From a theoretical standpoint, it was observed that studies addressing educational personalization in the contexts of blended and e-learning typically presented their proposals in the form of systems composed of modules. Four main modules were identified: student, instructor, knowledge, and personalization, with the first receiving the most attention across studies.

For personalization to occur, two key pieces of information about learners were predominant in what was called the student module: first, the learning style, and second, the level of prior knowledge regarding the subject to be studied. To

identify learning styles, the analyzed studies employed different models, including Felder-Silverman, Kolb, and Honey & Mumford, with Felder-Silverman being the most frequently used and cited. Once the model was chosen, students were categorized using one of two strategies: (1) applying questionnaires or (2) using techniques/algorithms that classified students based on their interaction patterns within the system. In relation to knowledge level, questionnaires were also the primary tool employed for assessment.

It was noted that the instructor and knowledge modules were similar in their functions and processes. In summary, both were responsible for uploading learning materials into the system in various formats to accommodate learner heterogeneity, based on the parameters previously mentioned. However, the design and development of such materials required the conceptualization of the course or subject to be offered, highlighting elements such as chapters, concepts, and learning objects.

Finally, the personalization module was described as a mechanism capable of using information from both the instructor/knowledge and student modules to provide the most suitable content for each learner's needs and context—thus personalizing the learning experience. To achieve this, advanced techniques such as machine learning, big data, and algorithmic modifications to existing LMSs (Learning Management Systems) were often employed.

Concerning the second specific objective and the study's practical contributions, a framework was proposed, grounded primarily—but not exclusively—on the SLR findings. The proposed structure was also designed in modular form: student, knowledge, and personalization modules. It was argued that two pieces of learner information are essential: (1) the learning style, based on the Felder-Silverman model, and (2) the level of knowledge regarding the topic to be studied. Both should be identified through questionnaires, selecting two of the four Felder-Silverman dimensions and categorizing prior knowledge as either high or low.

Additional theoretical contributions related to this second objective lie in the systematization of the necessary steps for personalizing educational processes in blended learning contexts, based on both the literature review and the proposed structured framework. By organizing the procedures involved in learning personalization in a clear and logical manner, this study provides a useful guide for future research and practical applications, assisting educators and system developers in

creating more adaptive and learner-centered educational experiences. This contribution broadens the understanding of personalization in hybrid environments and provides a solid foundation for advances in both theoretical exploration and innovative educational practices.

Furthermore, this study discussed the structure to be used for the planning, design, and implementation of a course or subject, indicating the essential elements of the knowledge module. It was argued that a Learning and Teaching Plan (LTP) should outline the general objective, learning objectives, and materials, ensuring coherence among these elements and with the chosen personalization spectrum—whether more aligned with andragogy or heutagogy—based on context, existing literature, and material availability. Ultimately, the personalization module integrates the information from the other two modules to ensure the delivery of the most suitable materials according to learners' realities.

Although this study provides a significant contribution to understanding personalization within blended learning contexts, some limitations must be acknowledged. First, the research focused on a Systematic Literature Review (SLR) of articles published only in Portuguese and English, which may have introduced bias and limited the generalizability of findings to other linguistic and cultural contexts. The choice of databases also reflected the authors' prior knowledge, potentially omitting other relevant perspectives. Moreover, the proposed framework has not yet been empirically validated, preventing a deeper analysis of its effectiveness in real-world learning environments. The lack of empirical data also restricts comparative analyses between experimental and control groups, which could better demonstrate the framework's practical impact.

Another relevant aspect concerns the scalability of the proposed model, which may face challenges when implemented in large-scale educational environments, particularly regarding data management and adaptive content delivery. Additionally, while the study emphasized learners' learning styles, other influential factors—such as emotional engagement and socio-emotional competencies—were not addressed, even though they also play an important role in learning and personalization. The technological limitations of current LMSs must also be considered, as implementing machine learning and big data solutions may be unfeasible in many contexts due to cost or lack of infrastructure.

This research opens several avenues for future studies, both practical and theoretical, that could deepen the understanding of personalization in blended learning environments.

In the practical field, it is essential to conduct applied studies that implement the proposed framework in real educational settings. Empirical investigations—particularly controlled trials with experimental and control groups—could provide concrete evidence of personalization's effectiveness and its impact on learners' performance and engagement. Furthermore, integrating emerging technologies such as artificial intelligence, augmented reality, and virtual reality could make learning experiences more immersive, adaptive, and interactive. The framework can also be adapted to different educational contexts and learner profiles, such as early education, higher education, or corporate training, respecting each context's specific needs.

Another important aspect is the promotion of learner autonomy, allowing students to define their own learning objectives and select the materials they wish to engage with—thus aligning the process with a heutagogical approach. Longitudinal evaluations of outcomes derived from the framework implementation also represent a promising research avenue, enabling the assessment of personalization's long--term effects. Finally, integrating formative assessment processes into the model could support continuous and individualized adjustments to the learning path, fostering a more dynamic and student-centered experience.

In the theoretical field, there are opportunities to expand knowledge about the effectiveness of personalization. One line of inquiry could explore which dimensions of the Felder-Silverman model exert the greatest influence on learning outcomes within the proposed framework. Additionally, theoretical exploration could focus on the effectiveness of different types of instructional materials—such as texts, video lectures, hands-on exercises, and case studies—when applied to different learner profiles. There is also a need to develop new theoretical models and frameworks that advance understanding of personalization in hybrid learning contexts, particularly through the integration of open-source platforms. Finally, studies exploring the interoperability between various LMSs and personalized frameworks could broaden understanding of how personalization theories can be adapted across multiple technological environments.

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