Designing and Representing Learning Itineraries: A Systematic Review of the Literature.

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Abstract. Designing learning in higher education involves developing teaching-learning strategies adapted to the individual characteristics of students. Therefore, it is necessary to create models that facilitate the creation and dissemination of learning itinerary designs. This review aims to identify characteristics of the models design for learning itineraries in higher education. The methodology used is the systematic review at the level of meta-analysis following the PRISMA protocol. The 28 articles selected for mapping and synthesis allowed the identification of characteristics of the studies, the structure and the pattern language of the designs, the personalization strategies, the elaboration methodology and strategies to evaluate the results of the implementation of learning itineraries. In conclusion, designers and teachers showed a tendency for an own design, therefore it is necessary to extend the existing knowledge about its implications in the educational practice, and the construction of knowledge is directed to the models design.

Keywords: learning itinerary, adaptive learning system, higher education, design patterns, systematic literature review.

1 Introduction

Trends in the design of learning in higher education are accompanied by the planning of technology-enhanced learning (TEL) activities [1]. In this sense, planning implies that teachers develop learning strategies that are adapted to the needs and resources of the student; that is, transforming teaching and obtaining an adaptive learning that can be applied to any educational modality.

Among the solutions to adapt learning are smart learning systems, included in technology-enhanced systems. These, in the first instance, provide the user with the

possibility of interacting with digital learning resources by eliminating the barrier of time and space. Also, these provide support tools, recommendations and adaptation [2].

In adaptive learning, each student follows an individual learning itinerary tailored to his or her goals, ability to perceive and process information [3]. In the existing alternatives to adapt the learning, (people and technology), the teacher is fundamental to create and organize the contents, learning objects, assessment and sequence them coherently to obtain effective educational results.

From this perspective, it is necessary to think that teachers require a model that facilitates the creation and dissemination of learning itinerary designs. Therefore, it should be noted that the design of a model fulfills the function of disseminating knowledge about experiences in the field of teaching and learning, so that it can be reused to optimize the work time and effort involved [4].

The systematization of the literature shows the scope of research on learning itineraries, also called learning paths. In [5] a systematic review was carried out on the strategies of organization, representation and management of learning paths. This work identifies proposals of representation of learning paths based on ontologies and deduces that there are few solutions for visualizing learning itineraries from the student's point of view. On the other hand, the work of [6] is focused in identifying, analyzing and classifying adaptive learning systems used to recommend learning paths. The results show that these systems are in a basic development stage, and divide them into adaptive decision tree systems, adaptive rule-based systems, adaptive systems based on automatic learning and, adaptive systems of advanced algorithms. Likewise, the authors identify that in the reviewed works there is no comparison with existing solutions and some lack rigorous statistical analysis.

However, it is necessary to expand the existing knowledge on the design of learning itineraries in terms of actors involved, personalization strategies, pattern language, structure and ways to evaluate the results of the implementation, which will lead to the formalization of replicable models in educational practice.

In view of the above, and based on a thorough review of the literature, research that addresses the systematized presentation that links the characteristics of the models design for learning itineraries in higher education is incipient. Given this situation, this study assumes this research gap and we contribute to the detailed identification of key ideas associated with the formalization of learning itineraries that have been published in high impact peer-reviewed journals, being understood as a perspective of educational research in this field. The results of this systematic review will allow us to identify the contributions and focus of academic discussion on this topic.

From this perspective, this work reviewed, classified and synthesized research related to the characteristics of the design of models of learning itineraries in higher education based on the following questions:

- What are the characteristics of the studies that have referred to the design of applied learning itineraries in higher education in terms of study design, theories, technologies and stakeholders?

- What is the relationship between the terminology used in designing learning itineraries and adaptive learning?
- What are the methodologies for developing learning itineraries and their relationship to personalization strategies?
- What is the pattern language and structure used in designing learning itineraries?
- What are the strategies used in the studies to evaluate the results of the implementation of learning itineraries?

2 Theoretical Background

In order to understand the issues addressed in the systematic literature review, this section presents from an educational perspective, the concepts related to learning itineraries, learning sequences and adaptive learning systems.

2.1 Learning Itineraries

The learning itineraries are as a concept map that guides the student in learning about a particular topic [7]. In [8, 9], they explain that a learning itinerary guides the students through the contents, processes and activities and, simultaneously, grants flexibility and autonomy in the learning process. On the other hand, in [10] they state that it "acts as an organizer of both the concepts, themes, etc., to be learned, and the learning objects to be used, giving a complete vision of what must be done to understand a subject in question or to develop a specific competence".

In the context of the design of learning itineraries, the binomial flexibility and personalization is included [9]. The concept of flexibility, from different approaches in education, can be understood as meeting the needs of the student through the adaptability of the media [11], flexibility of time, content, conditions for participation, instructional approach, distribution and logistics [12], teaching and learning approaches centered on the student, with degrees of freedom in time, place and teaching and learning methods, [13]. Last but not least, personalization emerges as an alternative to the so-called "one size fits all" approaches to education, i.e., thinking in terms of a student-centered methodology that considers individual learning goals [14], their background [15], and co-designing to develop an education plan that works for them, thus increasing learning commitment and achievement [16].

2.2 Learning Sequence

Research on learning sequences is related to the organization of content, taking into account reactions, behaviors or learning demands, divided into appropriate stages to enable the

understanding of the subject in question [17]. Likewise, [18] it assumes that it is a process of reflection on the organizing content and the different levels of elaboration in which it should be structured. For its part, [19] it refers to the design of learning organized carefully to achieve learning objectives, taking into account some pedagogical principles, resources and support mechanisms.

The essential purpose of the design of learning sequences is the likely influence it has on student achievement and performance [20] and, specifically, personalization learning objects and assessment appropriately so that they are appropriate to the student's level of skill [10].

2.3 Adaptive Learning Systems

Adaptive learning systems are primarily technology and data driven. Their architecture is composed of learning objectives, learning objects, and assessment activities arranged in sequences individually adapted to the students [21]. One of the main objectives of its implementation in education, in essence, is related to improving the efficiency of the design, reordering and sharing of learning paths [2].

The adaptive learning ecosystem can be generally classified into Decision Tree Adaptive Systems (DT),Rules Based Adaptive Systems (RB), Machine Learning-Based Adaptive Systems (ML) and, Advanced Algorithm Adaptive Systems (AA) [6].

The first ones are based on probability rules represented in decision trees, which determine student's workflows and are assigned individualized learning paths at an established rhythm based on rules [14]. Generally, this type of system does not consider a specific learning profile of the student [22].

Rules Based (RB) adaptive systems are predetermined by rule sets to filter and model the learning path [23]. In these systems, personalization is carried out by evaluating previous knowledge [16].

Consequently, the machine learning-based adaptive systems, is perhaps, the most advanced method in this field. The architecture of machine learning uses pattern recognition, statistical modeling and predictive analysis [24]. It is primarily designed from algorithms that determine the competence of students, and in real time, assigns a learning path based on their preferences [25].

Finally, advanced algorithm (AA) adaptive systems collect information based on the transactional behavior between student and computer. In this case, it registers click flows, time intervals, evaluation attempts and links them to a student profile [26]. This allows to scale a personalized learning path that is constantly compared with others assigned to other students exposed to the same or similar content [27].

Up to this point, it should be noted that the models that use these systems to generate learning paths provide important elements for our theoretical framework. On the other hand, it is necessary to highlight the role of teachers in adaptive learning systems, since it has been clearly demonstrated that teachers are fundamental, and that these systems operate

optimally as part of an educational ecosystem, and should not be seen as separate entities to educate students [28].

3 Method

The methodology used to achieve the research objective is systematic review, because it contributes to the understanding and evaluation of the evolution of the scientific production of a particular subject [29]. Likewise, systematic reviews, in the words of López, Méndez, Paz y Arboleda [30] "allow for an evaluation and interpretation of the available documentation for a particular subject, through the application of a reliable, rigorous, auditable and repeatable process".

Based on the above, the review was carried out using the PRISMA protocol for systematic reviews and meta-analysis [31].

3.1 Purpose and Search Strategy

This step included the definition of the object of study and the identification of search strategies. A reflection on the subject allowed to establish that the purpose of the review was to identify the key ideas associated with the formalization of learning itineraries that have been detailed by the researchers. Then, the search strategies for the initial corpus of documents were defined. The criteria that were taken into consideration were:

The information sources come from databases (SCOPUS, Web of Science, DOAJ, and ERIC) and the document type are peer-reviewed articles. It should be mentioned that in this systematic review unpublished publications or gray literature are not considered, since in some cases they are not exposed to a peer review process, include provisional conclusions or selectively report the results [32]. Considering the words of Zawacki-Richter et al. [33] it is pertinent "to include only high-quality research and to minimize the possible impact of multiple publications based on the same data set".

The search descriptors used result in the following string of keywords: ("learning itinerar*" OR "Training itinerar*" OR "learning organizer" OR "Learning sequence" OR "Learning path*").

3.2 Eligibility Criteria and Study Selection

The search was limited to the social sciences, the arts and humanities, computer science / information technology area and education technology. This criteria component made it possible to exclude many results in fields other than education that were not relevant to the review questions.

Initially, a date restriction was applied, and it was considered appropriate to limit the review from 2010 to 2020.

Finally, documents will be pre-selected only if any word in the above-mentioned keyword chain appears verbatim or is clearly associated with the title or abstract, and if they present research results.

Inclusion/exclusion criteria for determining the eligibility of documents can be seen in Table 1.

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Studies that have thematic relevance to personal learning itineraries	Studies that relate personal learning itineraries to the development of course sequences within the curriculum
Studies that focus on the design of a platform that supports distance or presential education and implements recommending systems for the development of personal learning itineraries	Studies that implement recommending systems in educational platforms without following a learning itinerary
	The concept of learning itineraries is focused on the decision/behavior that a student assumes in order to choose an academic program of university or postgraduate training
Higher Education	Levels different than Higher Education
Publication type: Full article	Publication types different from articles
Empirical and theoretical studies that proposed models	
Focus on Educational Studies	Focus on other studies outside Educational Studies
English or Spanish	Languages different from English or Spanish

The preliminary search yielded 1174 articles related to personal learning itineraries, distributed in the four databases consulted as follows: Scopus (595 documents), Web of science (466 documents), DOAJ (21 documents) and ERIC (92 documents).

Later, the results were exported to Rayyan, a free web application that automates the filtering of titles and abstracts, and in parallel incorporates a high level of usability [34]. After this process, 344 duplicates were eliminated, which limited the review to 830 articles.

Afterwards, the criteria of exclusion/inclusion were applied, allowing 48 documents for a more in-depth reading. Afterwards, 28 articles remained from the in-depth reading for mapping and synthesis. In Figure 1, the complete process and the reduction of articles can be seen.

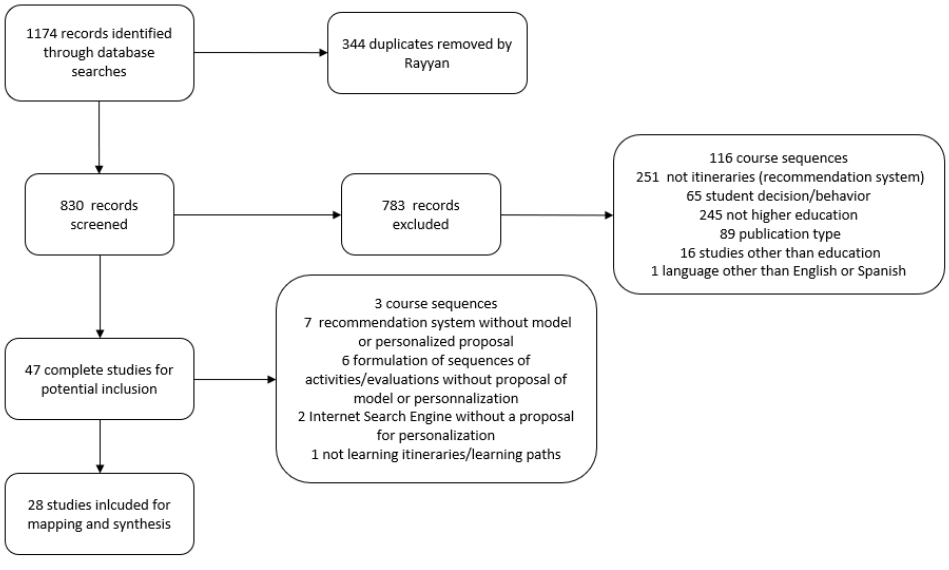

Fig. 1. PRISMA Scheme (based on [35]).

At this point it is necessary to highlight some observations regarding methodological decisions and the limitations of this systematic review. First, some articles that made proposals of theoretical models for the formalization of itineraries learning were included, as they provided some valuable research ideas. Secondly, we consider that the development of recommending systems of learning objects applied to education, can contain in their proposals models for formalizing learning itineraries, therefore, we reflect that it is relevant for this research, to include them in the corpus of documents for mapping and synthesis. Finally, it is worth mentioning that the search strategy (descriptors used and databases) as well as the inclusion/exclusion criteria (type of publication, language and higher education) may be limitations, but this does not mean that the systematic review is not a process with systematic, explicit and responsible methods [36].

3.3 Data Extraction

The 28 articles selected for the mapping and synthesis were exported to NVivo (version 12), a qualitative data analysis software [37], to be able to make the coding process.

The initial categories applied in the coding phase emerge from the research questions. The first categories are related to the characteristics of the article (year of publication, country of authorship), the study design (theoretical or empirical), and the theory behind the study, according to the design of pedagogical patterns [4]. In the coding of theories, some articles did not specifically report their assimilation to one, therefore, we coded

considering the identification of some of their key elements (importance of prior knowledge, collaborative construction, cognitive processes, implementation of common knowledge within the learning community) and leading to a shared understanding in the research team.

For the categories personalization strategies, pattern language, technologies, stakeholders and strategies to evaluate the results of the implementation of the learning path, we identified the co-occurrences in the articles to extract the codes of each category.

As for the category elaboration methodology of the learning itinerary, the classification reported in [6] was used, but it was necessary to include other forms of design that are related to representation strategies through node schemes and the use of repositories.

Finally, in the category structure of the model, as they are learning designs, each article reports different activities to document the procedure of designing the learning itinerary or the adaptive learning system. Therefore, we reflected on the need to group the activities by dimensions, as it was done in [38] and the descriptive dimension was included, as proposed in [39].

3.4 Data Synthesis

The coded data were exported to an Excel matrix to reorganize and merge the codes into categories. This allowed to establish agreements in the different codes and their classification in the categories. Therefore, the final coding system, including the categories and codes, can be seen in Tables 2 and 3. A qualitative analysis was also carried out to make a broader approximation of the extracted information. Under this scenario, we present the results according to the research questions.

Table 2. Categories and codes (I).

Study design		Theory behind the study	Terminological variations	Personalization strategy	Pattern language
Theoretical	Quantitative	Social Cognitive Theory	Learning itinerary	Entry test	Layers
	Qualitative	Meaningful learning	Learning path	Learning style	Components
	Mixed methods	Social constructivism	Learning pathway	Learning history	Schemes
		Connectivism	Learning sequence	Learning progress	Models
				Social interactions	Modules

	Co-design of learning material	Moments
	Navigation history on learning paths	Ontologies
	Student sequence selection	Steps
	Concept navigation	Processes
	Student preferences for specific formats of study material	
	Understanding previous schemes	
	Time available for a lesson	
	Self-regulated learning	
	Precedence rules	
	Context and environmental influences	
	Learning interests	

Table 3. Categories and codes (II).

Pattern methodology	Design structure	Technologies	Stakeholders	Implementation Assessment
Decision Tree Adaptive Systems (DT)	Descriptive Dimension	Website	Researcher	Learning achievement
Rules Based Adaptive Systems (RB)	Pedagogical Dimension	Desktop application	Teachers	Students' assessment

Machine Learning-Based Adaptive Systems	Organizational Dimension	Learning Management System (LMS)	Students	Probabilistic Inference
Advanced Algorithm Adaptive Systems (AA)	Technological Dimension	Social network		Performance Indicators
Repository				Required learning time
Concept map				Learning sequence assessment
Structured path				Expert Assessment
				Comparison between learning paths
				Teacher's assessment

4 Results

4.1 Characteristics of the studies

Within this section, we analyze the characteristics of the sample, in terms of the year of publication, country of authorship, study design, the theory behind the study, technologies and the stakeholders.

To begin with, the interest in studying the generation of learning itineraries has been growing since 2017 (see Figure 2), with 2019 and 2020 being the years with the highest number of references. It should be noted that productivity in 2018 did not decrease, this is because the titles of the articles, do not focus specifically on our research, so it is an indirect effect.

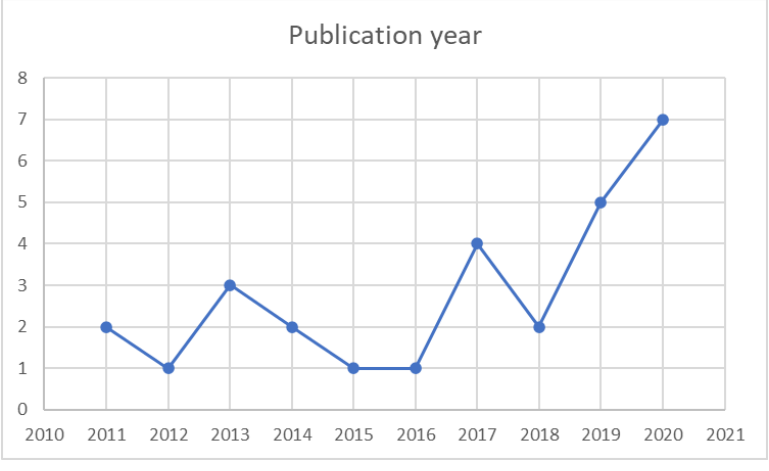

Fig. 2. Publication year of the studies (n=28).

The geographical distribution of the articles was analyzed based on the country of affiliation of the first author. Table 4 shows that authors from 13 countries participated in the articles in our sample. China (n=5), Taiwan (n=5), Spain (n=3) and Morocco (n=3) are the main contributors in our sample. Of the above, two from Spain were written in Spanish, and the remaining fourteen in English, although they are not English-speaking countries.

Table 4. Articles by country (n=28).

Country	Number	References
China	5	[15, 26, 48, 55, 66]
Taiwan	5	[45, 50, 51, 56, 58]
Spain	3	[10, 44, 46]
Morocco	3	[23, 54, 59]
India	3	[16, 40, 41]
United States	2	[27, 42]
Algeria	1	[53]
Argentina	1	[57]
Belgium	1	[47]
Canada	1	[49]
Iran	1	[52]
Italy	1	[2]
Portugal	1	[22]

In terms of study design, most of the works in the sample were quantitative empirical (n=15) followed by theoretical studies (n=6) (see Figure 3). Studies that used mixed methods (n=4) or exclusively qualitative methods (n=3) were less common.

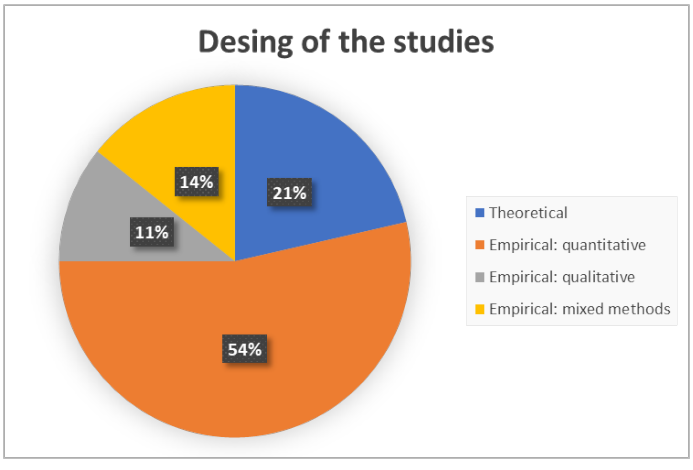

Fig. 3. Design of the studies (n=28).

The theoretical constructions that shaped the development of the learning itineraries design came from the psychological disciplinary tradition (See Table 5). The theories that are most often presented in the studies are social cognitive theory (n=9) and meaningful learning (n=8). Mainly, in the studies that were designed with the social cognitive theory perspective, the development of strategies based on input tests (e.g., [40]) and self-report questionnaires to determine learning style (e.g., [41]) was evidenced. The studies that reported their design through meaningful learning, a sequential relationship was found in the development of pathways (e.g., [10]) and sequences of learning (e.g., [42]), indicating that one concept should be learned before another, based on Ausubel's assimilation theory [43].

Table 5. Theory behind the study (n=28).

Theory or theoretical construction	Number	References
Social Cognitive Theory	9	[15, 16, 26, 40, 41, 45, 52–54]
Meaningful learning	8	[10, 42, 46, 49, 56–59]
Connectivism	6	[22, 23, 47, 48, 55, 66]
Social constructivism	5	[2, 27, 44, 50, 51]

Likewise, designs based on connectivism (n=6) and social constructivism (n=5) were found in smaller proportions. Although all the studies were designed in systems where technology plays a meaningful role, in the designs through the theory of connectivism an interest in platforms and knowledge management hosted in databases was identified (e.g., [22]). Respectively, the studies characterized in the sample, designed from the theory of social constructivism, showed co-design activities of the learning material (e.g., [2]) and strategies based on the context and influences of the environment (e.g., [44]).

Turning to the technologies used/mentioned to implement learning itineraries (see Figure 4), in the sample it was identified that websites were the most used. In other studies, LMS were used as Moodle (e.g., [45]) and LAMS (e.g., [46]). The use of social networks (e.g., [27]) and desktop applications (e.g., [47]) was also reported. Finally, some studies did not report the implementation of technology because they were theoretical studies (e.g., [26]) or there is no evidence in the study (e.g., [48]).

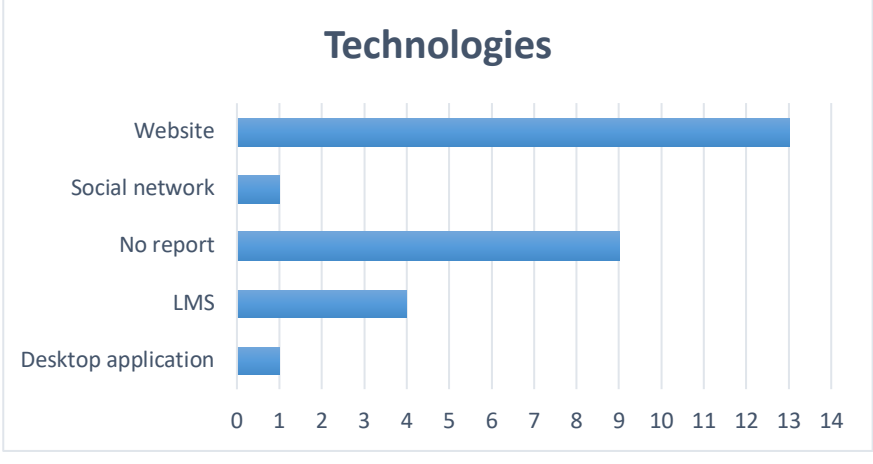

Fig. 4. Technologies used to implement learning itineraries (n=28).

Finally, it was important for we determine the stakeholders in the design of the learning itinerary, since this perspective mainly determines the role of teachers and students as creators, disseminators or consumers of adaptive learning materials (see Table 6). In the sample we found studies carried out by the researcher (n=16), collective between researcher and teachers (n=6) and, co-design between researcher, teachers and students (n=6).

Table 6. Stakeholders in the design of learning itineraries (n=28).

Stakeholders	Number	References
Researcher	16	[15, 16, 22, 23, 26, 42, 45, 47, 49, 52, 54, 55, 57-59, 66]
Researcher - teacher	6	[40, 41, 44, 46, 48, 56]
Researcher - teacher - student	6	[2, 10, 27, 50, 51, 53]

4.2 Relationship between terminology used in designing learning itineraries and adaptive learning

The terminology used in the studies to name the designs was, learning paths (n=20), learning pathway (n=4), learning sequence (n=3) and learning itinerary (n=1) (see Table 7).

In this sense, the term learning paths was used with the purpose of describing a defined path to follow learning objects [41], sequence of concepts and activities [16, 47], sequence of learning units and navigation map according to the learning cycle [15], appropriate system to guide learning [49]. These purposes are contained in the definition of learning itineraries arranged in [10]. Now let's see, the terms pathway and path, in English have the same meaning. Therefore, the identified terminological variations, learning paths and learning pathways used in English and learning itineraries, used in Spanish, are equivalent terms. From the above, it is understood in the context of this research that the terms mentioned are synonymous.

Table 7. Terminology used in the design of learning itineraries (n=28).

Terminology	Number	References
Learning paths	20	[2, 15, 16, 18, 22, 26, 40, 41, 45, 47, 49, 52-59, 66]
Learning pathway	4	[23, 27, 42, 44]
Learning Sequence	3	[46, 50, 51]
Learning Itinerary	1	[10]

With respect to the term learning sequence, it was used in the sample for the organization of concepts and activities [16], organizer of resources [40], organization of the units and help units [15], and repository of activities provided in a granular form [10, 46, 50, 51]. Interestingly, only one study establishes that it is similar to a learning path [52].

As for the relationship between the terminology used and adaptive learning, the term "adaptive learning paths" was found in twenty-six studies of the sample. This conception was referred to for systems that favored the automatic construction of flexible conceptual representations for students whose rhythm is the variable [49]. Likewise, they helped to reduce cognition [52], allowed for social interaction [27] and, provided a correct adaptive sequencing based on the requirements at the request of the student [42]. Although we think that adaptive learning is a broader concept, we established these constructs as a starting point in the discussion of the results, so that their inclusion is understood as a perspective of educational research in this field.

4.3 Methodology for developing learning itineraries and their relationship to personalization strategies

The methodologies found in the studies to design learning itineraries are divided into three groups, smart adaptive learning systems, classified according to [6], graphical representation systems and repositories (see Table 8).

Based on this framework, in the smart adaptive learning systems the most implemented in the sample are the ontologies (e.g., [53]) and the ant colony algorithm (e.g., [26]). Here it is worth mentioning that we found hybrid implementation methodologies between

decision tree adaptive systems (DT) and rules based adaptive systems (RB), mainly using Bayesian Networks and the Semantic Web to increase the efficiency of learning paths generation and to favor adaptive learning [54].

Table 8. Methodology for elaboration of learning itineraries (n=28).

Methodology	Number	References
Decision Tree Adaptive Systems (DT)	7	
Ontologies (n=4)		[2, 44, 53, 59]
Bayesian Networks (n=2)		[15, 47]
Petri nets-based maps (n=1)		[51]
Rules Based Adaptive Systems (RB)	6	
Agent system (n=1)		[56]
Fuzzy logic (n=1)		[45]
Semantic Web (n=2)		[16, 57]
Hybrid systems (RB/DT) (n=2)		[23, 54]
Machine Learning-Based Adaptive Systems (ML)	10	
Unclassified algorithm (n=3)		[27, 50, 58]
Genetic Algorithm (n=2)		[40, 41]
Ants Colony Algorithm (n=3)		[26, 49, 52]
Evolutionary Algorithm (n=1)		[48]
Deep Search Algorithm (n=1)		[22]
Advanced Algorithm Adaptive Systems (AA)	2	
Combinational Algorithms (n=1)		[55]
Process Mining (n=1)		[66]
Graphic representation systems	2	
Structured paths (n=1)		[42]
Concept maps (n=1)		[10]
Repository "Alacena"	1	[46]

Likewise, in graphic representation systems, we find the implementation of structured routes that consist of software-generated schemes to assist in the navigation of concepts in a linear fashion [42] and itineraries represented from concept maps that encourage flexible navigation [10].

Another methodology implemented in this category was the use of a repository of learning sequences called "Alacena" in [46].

In addition to the methodologies for designing learning itineraries, there are also strategies for personalization. We found in the sample a significant number of strategies implemented in the studies, with the objective of making the learning itineraries personalized (see Table 9). It should be noted that, the most used strategy was personalization through the identification of the learning style (n=8).

Table 9. Personalization strategies. Note 1: several codes could appear in the same article. Note 2: In one study it was not possible to identify the personalization strategy [46]. On: Ontologies, Bn: Bayesian Networks, Pn: Petri nets-based maps, Sa: Agent system, Fl: Fuzzy logic, Sw: Semantic Web, Hs: Hybrid systems, Ua: Unclassified algorithm, Ga: Genetic Algorithm, Ac: Ants Colony Algorithm, Ea: Evolutionary Algorithm, Ds: Deep Search Algorithm, Ca: Combinational Algorithms, Pm: Process Mining, Sp: Structured paths, Cm: Concept maps.

Strategy	Methodology															
	On	Bn	Pn	Sa	Fl	Sw	Hs	Ua	Ga	Ac	Ea	Ds	Ca	Pm	Sp	Cm
Entry test				[56]				[50,58]	[41]	[49]						
Learning style	[59]				[45]	[16]	[54]		[40,41]							
Learning history							[23]	[27]				[22]			[42]	
Learning progress	[44]						[23]		[40]							
Social interactions	[53]															
Co-design of learning material	[2]															
Navigation history on learning paths		[15]												[55]	[66]	
Student sequence selection																[10]
Concept navigation				[56]												
Student preferences for specific formats of study material		[47]														
Understanding previous schemes			[51]													
Time available for a lesson												[22]	[55]			
Self-regulated learning						[57]										

Precedence rules		[48]		
Context and environmental influences	[44]			
Learning interests			[55]	[42]

Before continuing, it should be noted that in some studies of the sample, three personalization strategies were implemented simultaneously (e.g., [23, 55]) and in others, two strategies (e.g., [22, 40–42, 44, 56]). The remaining studies used a personalization strategy (n=20).

4.4 Pattern language and structure of learning itineraries design

In the category language of patterns, the construct used to characterize the architecture of the design of the learning itineraries was identified (see Fig. 5). Based on the results of the sample, the most representative expressions are components (n=7), models (n=6), and layers (n=4).

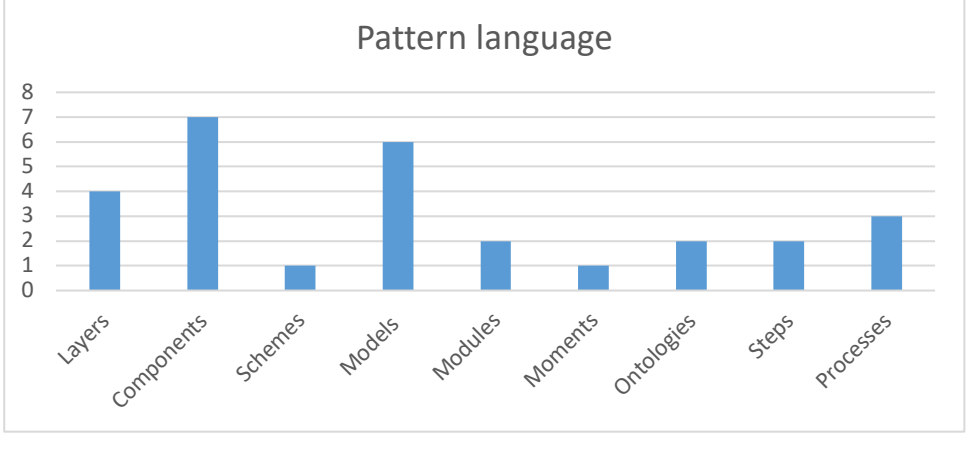

Fig. 5. Pattern language used to design learning itineraries (n=28).

As soon as to the activities/processes carried out in the architecture of each design model of the learning itineraries, it was necessary to group each code (Dimension) and attribute (Activities/processes), according to the conceptual reference mentioned in the stage of data extraction (see Table 10). It is worth mentioning that these results were constructed from

the schemes, stages and activities extracted from each study; however, it is possible that the authors have developed other activities/processes that were not mentioned in the articles.

Table 10. Structure of learning itineraries design. Note: several codes could appear in the same article.

Dimension	Attributes (Activities/processes)	Number	References
Descriptive (DD)	User characteristics	14	[15, 16, 26, 40, 41, 45, 47, 49, 50, 52-55, 59]
	Author's characteristics	1	[26]
	Training modality	1	[15]
Pedagogical (PD)	Metadata	4	[27, 46, 47, 66]
	Learning Objectives	3	[41, 51, 54]
	Context	3	[23, 44, 53]
	Problem situation	2	[2, 47]
	Solution Analysis	5	[2, 22, 27, 56, 66]
Organizational (OD)	Learning Objects	15	[2, 10, 23, 26, 27, 40, 44, 48, 50-52, 54, 55, 57, 59]
	Learning Paths	12	[10, 15, 22, 27, 42, 46, 48, 49, 55, 57, 58, 66]
	Entry tests	2	[50, 58]
	Flexibility	2	[42, 48]
	Learning Assessment	3	[22, 49, 52]
	User's assessment	1	[10]
Technological (TD)	Interface	13	[10, 16, 23, 26, 41, 44, 45, 47, 53, 55, 56, 58, 59]
	Learning object storage	3	[10, 52, 57]
	Resources of students	1	[46]
	Resources of teachers	1	[46]

In the studies it was possible to identify a number greater than two attributes that made up the structure of the design. In [57] a design was implemented from the description of the learning objects and learning path, which belong to the organizational dimension (OD). The same happened in [42], where they used the description of the learning path and the flexibility. In other designs, they combined two attributes and two dimensions, TD - PD (interface - solution analysis in [56]), DD - OD (user characteristics - learning objects in [40]), DD - TD (user characteristics - interface in [45]) and, PD - OD (learning objectives - learning objects in [51]).

In the group of studies that implemented two dimensions, the inclusion of three or more attributes was also presented. Based on the above, in [2] PD - OD (problem situation - solution analysis - learning objects), [58] OD - TD (learning path - entry test - interface), [50] DD - OD (user characteristics - learning objects - entry test), [16] DD - TD (user characteristics - interface - learning object storage), [22] PD - OD (solution analysis - learning path - learning assessment), [49] DD - OD (user characteristics - learning path -

learning assessment), [52] DD - OD (user characteristics - learning objects - learning assessment), and in [15] DD - OD (user characteristics - training modality - learning path). Also, there were found studies with implementation of four (n=1) and five attributes (n=1) respectively.

Finally, in the sample the combination of three dimensions and three activities/processes (n=6), three dimensions and four activities/processes (n=5), three dimensions and five activities/processes were reported (n=1). In the sample there is no evidence that a study has implemented all four dimensions.

4.5 Strategies to evaluate the results of the implementation of learning itineraries

For this category, the results allowed to determine the strategies used in each study to evaluate the results of the learning itinerary implementation (see Table 11). In the sample we identified that the investigation of user perception, through questionnaires and interviews (n=13), as well as the implementation of quasi-experimental designs of pre-test – post-test type with control and experimental groups, to identify differences at the level of comparison of means in learning achievement (n=11), were the most used techniques.

Table 11. Strategies to evaluate the results of learning itineraries implementation. Note 1: several codes could appear in the same article. Note 2: in [23, 26, 46, 57, 59] it was not possible to identify the evaluation strategy.

Strategy	Number	References
Learning achievement	11	[22, 27, 40, 41, 45, 48, 49, 53, 56, 58, 66]
Student's assessment	13	[2, 10, 16, 22, 41, 42, 44, 49-51, 53, 55, 56]
Probabilistic Inference	1	[54]
Performance Indicators	1	[47]
Required learning time	1	[58]
Learning sequence assessment	2	[27, 50]
Expert's assessment	1	[51]
Comparison between learning paths	4	[15, 44, 48, 52]
Teacher's assessment	3	[10, 51, 55]

Another situation that was extracted from the studies is related to the combination of two techniques (n=6). In this sense, the following binomials were found by learning achievement and students' assessment (n=5), learning achievement and learning sequence assessment (n=1), learning achievement and required learning time (n=1), learning achievement and comparison between learning paths (n=1), students' assessment and learning sequence assessment (n=1), students' assessment and comparison between learning paths (n=1).

Besides, other studies involved the collective made up of experts, teachers and students in the evaluation of results through interview reports and perception questionnaires (n=2). Another situation found in the results of the sample was the application of an evaluation

strategy (n=10). Finally, in a group of studies it was not possible to extract evidence of the application of an evaluation strategy because they were theoretical studies (n=4) and qualitative studies (n=1).

5 Discussion

The generation of learning paths adapted to the needs of students has been a topic of interest for researchers and teachers of higher education. This is due to the challenge of designing ecosystems that allow students to organize and customize their learning materials, thus helping them to achieve their learning objectives more effectively. This has increased the development of recommendation-based adaptive learning systems to filter information and deliver learning materials to students, which has undoubtedly changed the paradigm of teacher-centered education to a student-centered approach [47].

Based on the above, the responsibility of both researchers and teachers in building an integrative perspective of educational research in this field is meaningful. Therefore, this study reviewed, classified, and synthesized research related to the characteristics of the models design of learning itineraries in higher education between 2010 and 2020, to incorporate design elements other than the exclusive attention paid to the architecture attribute of the technological dimension. The discussion of the results found in each of the questions is presented below.

5.1 Question 1: What are the characteristics of the studies that have referred to the design of applied learning itineraries in higher education in terms of study design, theories, technologies and stakeholders?

All studies included in the sample addressed the design of learning itineraries using technology and data-driven systems that consolidate information on the student profile, learning objects, instructional resources, and assessment activities. Collectively, these elements are encapsulated in modular learning packages and provided in a phased-sequential fashion so that they can be adapted to students, reordered, or shared in other learning itineraries.

To achieve the above objective, the structure of the studies was carried out through theoretical and empirical research designs: quantitative, qualitative and mixed methods. The empirical-quantitative design was the most used because conclusions are usually based on significant evidence [60]. In this sense, the studies were structured by means of quasi-experimental methodologies of the pre-test – post-test type with control and experimental groups, to identify differences at the level of means comparison in learning achievement and to conclude whether or not the incorporation of the learning itinerary improves the educational process (e.g., [40]). Within the qualitative methodology prevailed in the studies, the implementation of interviews to nominal groups. This was presented because its

implementation allows the documentation of the experience of a group of students interacting with a learning itinerary (e.g., [42]). We found that the designs presented limitations in the reporting of results due to the subjectivity of the researcher and the lack of control in the unexpected variables, as well as bias in the selection of the population. In mixed methods, quanti-quali methodologies (e.g., [2]) and design-based research (e.g., [10]) were the most applied. This may be due to the feasibility when applied in small units, facilitating causal relationships and inference between research variables [61].

In terms of the theories behind the studies, those with a theoretical basis of meaningful learning and social cognitive theory, were the most frequently related in the design of learning itineraries. This occurs because their attention is focused on the design of learning objects and the planning of the sequences of content to be managed [4]. For the studies with a theoretical basis of social connectivism and constructivism, attention was identified to the context in which the learning processes take place (e.g., [51]), and the description and representation of the technological support resources (e.g., [23]). In view of this scenario, the results ratify what was stated in [28], the application of various theories behind the studies explains that it was designed for a given situation and context that conditions the design itself.

Regarding the technologies used to implement the learning paths, the use of websites developed in JAVA (e.g., [2]) and programming language PHP and databases in MySQL (e.g., [58]), were the most implemented because they present advantages related to flexibility in interface designs (e.g., [56]), favor the creation of modules for feedback and orientation of learning activities (e.g., [53]) and their architecture is installed in the cloud, minimizing robust physical systems (e.g., [50]). In the studies where LMS systems were used, it was identified that these systems have a great potential to measure the participation behavior of students in asynchronous activities (e.g., [45]), and compatibility for the reuse of learning objects, which are built with e-learning standards (e.g., [15]). Apart from this situation, the challenge faced by these technologies is to close the gap of interoperability between multiple technology systems, so that students can switch between content of the platform itself and a third party platform [3].

In this review, when verifying the role assumed by the stakeholders in the design of learning itineraries, we naturally find researchers and teachers assuming the leadership in the creation and dissemination of knowledge; a function ratified in [61]. However, another important result is related to the student's participation in the co-design or configuration of the elements that are part of the learning itinerary (e.g., [27]). This was mentioned in [10], to refer to the construction of a "true personal learning itinerary".

5.2 Question 2: What is the relationship between the terminology used in designing learning itineraries and adaptive learning?

To begin with, it should be mentioned that the identified terminological variations, learning paths, learning pathways and learning itineraries are equivalent terms, therefore, they were assimilated in the context of this research as synonyms. There is still an open path for future

research, determine whether the tendency to use the name "learning paths" in systems completely determined by technology has an effect differentiated from the other terms reported in the studies.

Now, in our review, we established a causal link between the design of adaptable learning itineraries and adaptive learning, based on the co-occurrence of the first concept, as well as the identification of specific actions that emerged on the border between the two constructs, which were reported in the studies' research results.

In this context, it is necessary to conceive the origin of the adaptable learning model. It brings with it, theories of self-regulation, such as the phenomenological, the cognitive, the information process and the social cognitive [62], where the learning episodes are associated to the goal, considering substantial elements such as motivations, identification, interpretation and control in learning [63]. In this model, the student from his motivations chooses his learning path [52]. Consequently, this model focuses on learning and the generation of an adaptable learning itinerary is not completely determined by technology [9].

In contrast, adaptive learning is a method that implements "learning analysis" [49], therefore its existence is determined by a software based technological system that uses data in real time to dynamically personalize the sequence of the contents, the evaluation, as well as its dosage [26].

Based on this frame of reference, an adaptive learning system requires a module of learning and evaluation objects, to conform the learning itineraries, so that the machine algorithms, based on the evaluation of the students' requirements, can make modifications in real time. It is necessary to clarify that an itinerary of adaptable learning can work without an adaptive system of learning, situation reported in [10, 46].

This scenario, in our view, opens a way to decipher the conditions of an ideal adaptable learning ecosystem where the "adaptive" and "adaptable" coexist, therefore, it is the work of future research to inquire into the perspectives of stakeholders in the context of educational research.

5.3 Question 3: What are the methodologies for developing learning itineraries and their relationship to personalization strategies?

We believe that the results show a growing interest of researchers to implement intelligent adaptive learning systems. Among the advantages we find, the possibility of reuse and exchange of educational content, confirmed by [64], as well as supporting the personalization of the learning process through real-time information of preferences and needs of students [57].

Other advantages that we highlight are related to the architecture and the size of the groups that can be addressed. Regarding the first one, these systems are based on data mining techniques, allowing an adaptive approach to productive and personalized learning, confirmed in [27]. Similarly, these can be applied in massive and open online courses (MOOC), characterized by not having a limit of participants (e.g., [47]).

However, the main drawbacks of these systems are related to the interoperability between systems, referred to above [3], the problem called "cold start", which prevents the system to automatically recommend the learning path, when it has no input data concerning the student profile [40]. Finally, the process of configuration of learning itineraries is carried out through the organization of learning objects, which in turn are extracted from the Internet through ontologies (e.g., [2]). This process does not guarantee the selection of quality content, since the learning objects are selected through deep search algorithms that recognize metadata based on e-learning standards.

Turning to the generation of learning itineraries through representation schemes, concept maps are a valid alternative that remedies the problem of content healing, the result of a work of material design by the teacher and co-design by students, referred to above. Likewise, they are adjusted to individual characteristics (needs, learning style, previous learning), proposed in [10] and are considered in [9] as a model of curricular design.

However, in the words of [56] "concept maps are ineffective for the study of large groups, particularly in classes of more than twenty students in which the teacher must dedicate considerable time to give personalized suggestions to the students".

In our systematic review we found that personalization was a strategy closely related to the design of learning itineraries. Its implementation is a process that provides the user with the best support to access information retrieval and storage according to its characteristics. In this sense, the use of learning style identification through standardized tests, VARK (e.g., [26]), Kolb (e.g., [16]), Felder-Silverman (e.g., [41]), was integrated as an enrollment requirement in adaptive learning systems. From our perspective, this managed to model a profile of the student to recommend a learning path based on his or her preferences.

However, other methods to achieve personalization were included in the studies. Input tests to detect prior knowledge (e.g., [58]) and learning history (e.g., [22]) were part of the range of strategies. In our reflection, these are strategies that must be complemented, since the tests to evaluate previous concepts depend on the individual's ability to retrieve information [65].

With sound criteria, in order to weigh the design of learning itineraries through smart adaptive learning systems, or with representation schemes, it is indispensable to think about the context in which personalized learning is provided [40]. In this sense, the challenge lies in formulating hypotheses, creating, and testing the best iteration of requirements that converge in the use of technology that monitors student progress and personalization developed by a teacher.

5.4 Question 4: What is the pattern language and structure used in designing learning itineraries?

Just as we saw that researchers have used various research and design methodologies behind the studies, we also found that there is no standardized pattern language and structure. The same was confirmed in [4] as follows: "design cannot be general, it is always designed for a certain situation and context that conditions the design itself".

In the studies, the constructs were identified: components, models and layers to describe the phases of the architecture or the activities/processes carried out in the designs. Strictly speaking, we identified that their inclusion responds to a semantic perspective that emerges from software engineering and is related to the reuse of solutions generated in this field.

It is possible that with the advance of new systems for the generation of design of learning itineraries, more terms will emerge, so we consider it relevant to reflect on three aspects necessary for the decision making of those who design. Firstly, it is fundamental that the elements that make up each of the dimensions are defined in the studies, so that there is a path that avoids starting from scratch to minimize the effort of synthesizing what the keys to success are and consequently, increase interoperability and the reuse of solutions.

In the process of developing models, we believe that researchers, being experts in their field, find it quite easy to develop their solution, in this case the learning itinerary, but present some difficulties in the drafting of the design methodology. The most important challenge is to manage to describe the solutions avoiding that their description is generic or to connect it with other design patterns so that they can be replicated.

Finally, we agree that another relevant aspect is related to the dissemination of design patterns. As the use of a common language and methodologies is still limited, this needs to be solved by dissemination with a greater emphasis on educational research, and the development of communities of teachers to encourage collaborative work and share experiences of good practice.

5.5 Question 5: What are the strategies used in the studies to evaluate the results of the implementation of the learning itineraries?

The analysis and evaluation of the results of the scientific activity is an important element that outlines a path to propose new studies, develop techniques and instruments. Properly in the context of the studies of our review, it serves to generate a model that evaluates the results obtained in such a way that they can be used effectively in the design of an ecosystem for the implementation of learning itineraries.

In view of the results, research on user perception (e.g., [2]) and quasi-experimental designs to assess the effects of an intervention at the level of learning achievement with control and experimental groups (e.g., [40]), were the most used techniques in outcome assessment on the implementation of learning itineraries. One of the reasons that justify this methodological decision is because the objectives and the design of the research itself guide the way in which the researcher evaluates the results [66]. In terms of the internal consistency of the instruments applied, it should be noted that the studies reported the implementation of Cronbach's Alpha coefficient (n=3), to measure the reliability of a scale of measurement in the user's learning achievement and assessment (e.g., [53, 56]), as well as learning achievement and required learning time, in [58].

In other studies of the sample (n=16), despite implementing tests to measure learning achievement and the comparison of learning paths, it was not possible to identify a model

that would allow us to see the process of operationalizing the phenomenon or the design of the instrument. Without specifying that these studies lack rigor, we reflect that the variety of techniques for collecting information and the analysis of internal consistency and reliability of instruments, ensure that the results obtained can be effectively used for replication.

Based on the findings, we consider that in future work it is important to consider the evaluation model for the design of learning itineraries, in addition to include the mentioned strategies, it takes a prolonged period of time to evaluate the conditions of implementation. This responds to the fact that the design of learning itineraries is a function of individual characteristics (needs, learning style, previous learning), which when modified, can produce changes in the design of the itinerary. However, we understand that it represents an obstacle because it does not speed up its introduction and possible generalization in the scientific field.

6 Conclusions

In this paper, we present a systematic literature review to identify characteristics of model designs of learning itineraries in higher education. Likewise, a mapping and synthesis of the literature was carried out to present a complete picture of this field of research. We followed the PRISMA protocol to reduce bias and provide a reproducible study. During the review and mapping, we started with 1174 articles identified from the selected electronic sources. After the inclusion/exclusion process, 28 studies were fully analyzed.

We point out that initially a variety of characteristics of the studies were explored; based on this, the growing interest in exploring the implementation of learning itineraries is evident, especially in countries of the European and Asian continents. However, we found diverse research designs and theories behind the studies, revealing research opportunities. We support studies that aim to explore the application of multiple research designs and different theoretical bases if they help the learning process and are based on consistent learning theories.

Despite finding a trend among designers and teachers for a design of their own, it is realistic to believe that each can contribute with their knowledge to the creation of a model structure for the design of learning itineraries composed of successful reusable strategies and solutions.

These findings leave an open path for learning itineraries design to be reformulated, so that existing knowledge about its implications in educational practice is expanded, and knowledge construction is directed to model design.

Based on the above, the models design of learning itineraries faces two major challenges: the methodology of elaboration and its formalization. Therefore, it will be possible to find designs to be shared if we use a standardized pattern of language.

The development of learning itineraries through the implementation of smart adaptive learning systems will obviously continue to advance, however there is a need for a

collaboration of researchers, teachers and students to express the next iteration of requirements needed in this ecosystem that requires interoperability of multiple systems.

Finally, it is worth designing assessment strategies for the implementation of learning itineraries in certain adaptive learning scenarios; since it is important to certify the way in which the student's knowledge structure is affected by the use of personalization strategies, platform implementation and representation schemes.

Supplementary materials: The data from the systematic literature review are available in open access at: https://tinyurl.com/y53hedrl

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