Formalization of a language for the construction of design patterns for learning

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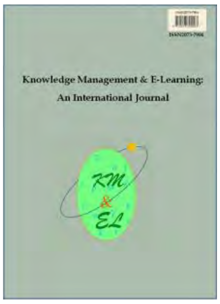

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Formalization of a language for the construction of design patterns for learning

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Abstract: Design patterns for learning are about articulating, testing and sharing the principles of problem solving in the educational context. In this way, multiple patterns are developed to solve common problems, described in various pattern language formats. Therefore, this work is about characterizing and establishing functional relationships between the components involved in the construction of a learning design pattern. The research was carried out in a Delphi study of double round individual non-contact between experts (n = 14), from different areas (educational technology, e-learning, distance education, higher education), selected through the coefficient of expert competence. The main result is a pattern language composed of attributes, components, and groups of processes. It is concluded that the language obtained allows externalizing knowledge from its consistent and shareable structure, which makes it suitable for use in different scenarios that require a formal pattern language and facilitates its implementation in online learning contexts.

Keywords: Design pattern for learning; Pattern components; Pattern language; Delphi method

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1. Introduction

A pattern is used when it is necessary to reproduce a solution to recurring problems. The term pattern was introduced by Australian architect Christopher Alexander to formalize knowledge about solutions to problems that occur over and over again, allowing the solution to the problem to be used indefinitely (Jiménez, 2009). There is multidisciplinary research around this concept, with important developments in the fields of software engineering, operations research and education (Martínez García, 2009).

In software engineering, a software design pattern is a general and reusable solution (Sriharee, 2020), which helps to standardize design concepts, capture experiences and reuse efficient solutions (Bafandeh et al., 2017). In the field of operations research, patterns correspond to representations of reality expressed in mathematical language, to represent decision variables and relationships that allow describing and analyzing the behavior of a system (Vanderbei, 1998). In the same tradition of seeking solutions for education in the science of design, design patterns have the explicit objective of externalizing knowledge about teaching-learning experiences (Laurillard, 2013), allowing reuse (Gros et al., 2016), and combine an articulation between the design problem and a design solution, to justify the relationship between pedagogical philosophy, research evidence and experimental knowledge of design (Goodyear, 2005).

However, when designing a pattern, whatever its field of application or subject is, its very definition leads to the development of a reusable work. In the words of González (2012): "Patterns [...] avoid reiteration in the search for solutions to already known problems, creating a standard in the design of solutions with the formalization of a language common to all designers".

The above appreciation, based on the contributions of Christopher Alexander, together with the works of (Bafandeh et al., 2017; Goodyear, 2005; Hadzhikolev et al., 2019; Sriharee, 2020), converge in the importance of implementing a common language of patterns, assimilating to a structured method that facilitates reusability and flexibility. It should be noted that the use of a language is a tool to facilitate communication between designers of different profiles and non-experts, and its standardization is not intended under any circumstances to limit creativity.

In education, the use of patterns and pattern language has gained interest in recent years. Here, each pattern design involves innovative work that tries to fit the personalized needs of students and resources of teachers (Dehbozorgi et al., 2018). However, being practice-based solutions, they lack a common language to represent the designs (Gros et al., 2016). Additionally, the literature review shows that many design patterns are constructs derived from Christopher Alexander's classical model, which result in sharing good pedagogical practices, but are not suitable for supporting online learning (Hadzhikolev et al., 2019).

From this perspective, the objective of this research is to characterize and establish functional relationships between the components involved in the construction of a learning design pattern.

2. Related work

2.1. Design patterns

Commonly, the word pattern is used to designate what is represented, that is, it establishes a relationship of satisfaction between a material object or behavior with a structure or description. But other times the word "pattern" or "model" is used to refer to a system that fulfills what the theory says. The latest is used especially in the sciences to describe a structure that represents aspects of certain real systems (Guerrero Pino, 2010).

According to Mosterín (1978), the patterns must have a structure, and this in turn must be associated with a theory. The same thing happens in the sciences when it is necessary to study a system that is little explored or complex. The process begins with the construction of a theory for a simple system, which has the simple system as a pattern, and finally, the same theory is applied to the complex system. In such circumstances, both systems are patterns of the same theory and, therefore, share structural properties.

Contemporaneously, Christopher Alexander proposed to include in the pattern language structure attributes referring to the context, the problem and the solution to the problem (González, 2012). This led to obtaining a structured method applicable to other fields.

Subsequently, software engineering implements the use of patterns to guide the user to design complex systems. In this field, a catalog of patterns (e.g., implementation pattern, test pattern, analysis pattern, and design pattern) were developed (Bafandeh et al., 2017).

The works developed in the educational field around design patterns start with technology-enhanced learning environments (TEL) approximately in 1999 (Philip, 2018), with great influence of Christopher Alexander's proposals and software engineering. In this field specifically they are denominated as "pedagogical patterns" (or learning patterns), "pedagogical design patterns", "learning design patterns" among others.

Some relevant works cited by Garzotto & Retalis (2009) include: the design patterns in the e-learning Pointer Project (http://www.comp.lancs.ac.uk/computing/research/cseg/projects/pointer/pointer.html), the E-LEN Project (http://www2.tisip.no/E-LEN/) and the TELL project (http://cosy.ted.unipi.gr/tell). In the Pedagogical Patterns Project (PPP) (http://www.pedagogicalpatterns.org/) cited by Goodyear & Yang (2009), they develop four pattern languages around: active learning, feedback, experiential learning and gaining different perspectives. Likewise, Seoane & García-Peñalvo (2014) cite the repositories (http://groupworksdeck.org), (http://lp.noe-kaleidoscope.org) and (http://www.cmi-patterns.org) which are characterized by the collaboration and approval of patterns in the educational domain.

2.2. Structure of design patterns

The literature review allowed us to identify studies in education and other areas of knowledge that use the attributes proposed by Alexander (1979). These include: the problem situation (Dehbozorgi et al., 2018; González, 2012; Goodyear, 2005; Gros et al., 2016; Iacob, 2011; Martínez García, 2009; Philip, 2018; Jiménez, 2009; Rolf et al., 2019), the analysis (Dehbozorgi et al., 2018; Eyal & Gil, 2020; Lotz et al., 2014; Martínez García, 2009) and the solution (Dehbozorgi et al., 2018; Eyal & Gil, 2020; González, 2012; Goodyear, 2005; Gros et al., 2016; Iacob, 2011; Lotz et al., 2014; Martínez García, 2009; Jiménez, 2009; Rolf et al., 2019).

Related works below expand the catalog of attributes. Dehbozorgi et al. (2018); Derntl & Motschnig-Pitrik (2005); González (2012); Gros et al. (2016); Martínez García (2009); Philip (2018); Jiménez (2009); Rolf et al. (2019), implemented the pattern name as a meaningful descriptor of the pattern, capable of succinctly conveying its essence. Dehbozorgi et al. (2018); Martínez García (2009); Philip (2018), incorporated the pattern metadata to provide high-level information of the problem addressed by the pattern. Likewise, Derntl & Motschnig-Pitrik (2005); Eyal & Gil (2020), González (2012); Goodyear (2005); Gros et al. (2016); Lotz et al. (2014); Philip (2018); Rolf et al. (2019); (Salinas et al., 2006), located the context as an attribute to state the situation or scenario addressed by the pattern.

Dehbozorgi et al. (2018); Derntl & Motschnig-Pitrik (2005); Goodyear (2005); Martínez García (2009); (Salinas et al., 2006), implemented justification in their work, as an attribute to describe pattern motivation. Other studies highlighted the importance of identifying related patterns to combine with the one in use (Goodyear, 2005; Iacob, 2011; Lotz et al., 2014; Martínez García, 2009; Rolf et al., 2019). Derntl & Motschnig-Pitrik (2005); Philip (2018), point out that pattern design requires attributes oriented to identify sequences of activities through schemas and their hierarchy, as well as the modality of the same activity (Dehbozorgi et al., 2018; Philip, 2018).

2.3. Construction of design patters for learning

The construction of design patterns for learning consists of applying inductive or deductive methods in a specific educational context to solve identified problems. This process is based on the experience and judgment of experts who collaborate in working sessions to share and systematize the designed learning scenarios (Seoane & García-Peñalvo, 2014). The design patterns follow a simple "context-problem-solution" format, where the context descriptors provide the framework, the problem is the learning outcome, and the sequence of activities describes the proposed solution.

Fig. 1. shows how the Pedagogical Patterns team (Bergin, 2012) captured the essence in a structured and concise way to arrive at a pattern that provides a solution to the following problem: How do you end a lesson in the classroom?

Fig. 2. shows another design pattern developed by an interdisciplinary team from the University of Cyprus and the National Technical University of Athens (Avgeriou et al., 2004). This pattern encapsulates a solution to a problem related to a learning management system, presented in an understandable and usable format.

Problem

How do you end a course?

Forces

You want to end a course, but you do not want the participants to run away.

In a course people might learn a lot of things, but at the end (even of a day) they are often unsure if the time was well spent.

Solution

Provide a wrap-up that repeats the main points learned.

- Minimum Wrap-Up: The minimum you should provide is a wrap-up of the day. Just mention every topic that has been covered and review the specific points people have experienced. You can turn this around and let the students do it. This is also known as *Flashlight*: Each of the participant mentions one item of the day that was important for her.
- Reflective Wrap-Up: Ask the people to write down e.g. three things they have learned in the course and one action they want to perform in the next two weeks, because of what they have learned. You do not have to discuss these things with the whole group, but it is better not to mention this up front, because otherwise people won't answer the questions seriously.
- Sweet Wrap-Up[1]: Invest in some sweeties. Pass them around and dispense one sweetie for every item or topic remembered.

Discussion

The *Minimum Wrap-Up* is very useful for summing up a session.
The *Reflective Wrap-Up* - although it could also be used in the same manner as the minimum wrap-up - is best for ending a whole section or course.
When you use *Sweet Wrap-Up*, your choice might not agree with the students' taste or it bankrupts you if the group is very big.

Fig. 1. Learning pattern: How do you end a course?

4.1.2 Management of on-line questionnaires

i. **Problem:** How can web-based quizzes be created, delivered and graded?

ii. **Motivation:** One of the main learning activities of the instructional process is students' assessment. Assessment is one of the main mechanisms for checking and monitoring students' level of knowledge. It is very beneficial for the instructor to assign particular questions to learning units where the student should check the knowledge she/he is supposed to have obtained. Assessment can be automated in order to save instructors' time and effort in delivering and grading tests. Automation also offers to learners the ability to perform assessment without any time and place constraints. However, the on-line administration (creation, delivery and grading) of tests for the assessment of students is a complicated task. The "Question and Test Interoperability" IMS standard acts as a guide for the creation of assessment tests.

iii. **Solution:** The system should enable the instructors:
- to create on-line both closed-end questions with predefined answers, that are able to be automatically graded and open-end questions, that need to be graded by an instructor
- to create/edit on-line closed-end questions of various types: multiple choice, fill-in the blanks, etc. and easily mention the corresponding right and wrong answers. The hint messages and/or feedback messages that will be shown to the student in case of wrong and/or right answer should be stated
- to administer the delivery of the online test. More specifically, the instructor should be able to state how many times an online test can be answered by the student, the duration of the assessment (time limits), to announce the schedule of on-line tests as well as their grading so that students get informed on time
- to be able to allocate a grade to each question of a test separately and/or to the whole test updating the students' records
- to search for possible questions, that could be integrated into a newly made test, in a pool of already made online tests. In some cases it is valuable to incorporate into a LMS a ready made questionnaire that appears in another LMS. Conformance to QTI standard for question interoperability is necessary in this case.

The system can optionally support adaptive question sequencing, customizing the succession according to which the questions are given to the learner. The answer to a particular question (right or wrong) might change the sequence of the test questions and the related study material according to specific sequencing rules.

iv. **User category:** Instructor, Learner.

v. **Known uses:** All LMS that were reviewed have some mechanism for on-line questionnaires.

vi. **Related Patterns:** Assignments management, Student tracking

Fig. 2. Learning pattern: Management of on-line questionnaires

Focusing more on design, Laurillard (2013) suggests that patterns function as small sequences of activities to solve a problem in an educational context. In this regard, Fig. 3 shows how the pattern developed in Fig. 2 “On-line questionnaire management” is part of a set of related patterns (Avgeriou et al., 2004). It should be noted that the relationships are established according to the specificity of the solution provided by the design pattern. For example, ‘Personalization’ and ‘Registration-authentication-access control’, are related because when a new function is inserted for a role, it also becomes a personalized entry depending on the courses in which the stakeholders participate. For better understanding, specific patterns are represented in yellow, while generic patterns are represented in green.

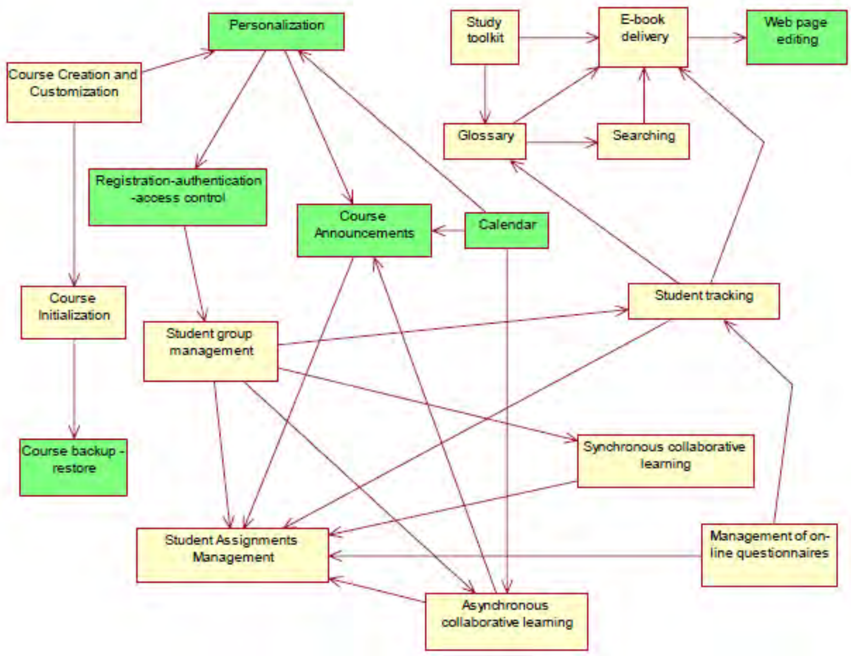


Fig. 3. Relationships between specific design patterns and generic design patterns

2.4. Methods to develop design patterns

The methodologies used to elaborate design patterns reported in the literature are the development of scripts (Dehbozorgi et al., 2018; Hadzhikolev et al., 2019; Lotz et al., 2014; Philip, 2018; Jiménez, 2009) and narratives (Eyal & Gil, 2020; González, 2012; Martínez García, 2009; Jiménez, 2009; Rolf et al., 2019; Sriharee, 2020). Scripts correspond to sequences of operations to obtain the solution to the problem and narratives are participatory and co-design methods (Gros et al., 2016).

In relation to the above descriptions, Derntl & Motschnig-Pitrik (2005) developed a pattern made up of packages that they called pattern definitions, preliminary phases and general package. Subsequently, the knowledge of experts in the field of e-learning was used in Salinas et al. (2006) to build a model that assigns elements to the pedagogical, organizational and technological dimensions. In turn, the authors implemented management levels in categories I, II and III to place the elements according to the intrinsic process executed when managing ICT-supported learning environments.

The design pattern model in Dehbozorgi et al. (2018) incorporates the components (e.g., pattern name, metadata, pattern core and implementation). Here, the schema shows a graphical representation of three blocks called level 1 attributes, level 2 attributes and value set.

Finally, Hadzhikolev et al. (2019) propose a model that is usually used for the description of pedagogical patterns composed of 4 layers. The authors contemplate in their design the e-learning context by adding requirements that are specific to this scenario.

3. Materials and methods

In this research, the Delphi method of multiple individual rounds and without contact between experts was implemented, because it allows to systematically collect the points of agreement and their level of consensus on the same problem according to its importance (Reguant-Álvarez & Torrado-Fonseca, 2016). Likewise, in the words of López-Gómez (2018): "Its development has to guarantee anonymity, establish an iterative process through feedback and is oriented towards a statistical measure of group response".

It should be noted that the Delphi method is not applied in this work to generate a consensus on the creation of a specific design pattern, but rather to explore divergent opinions and motivations on the incorporation of elements to be considered for the design of patterns for learning in e-learning. The procedure carried out in the investigation can be seen in Fig. 4.

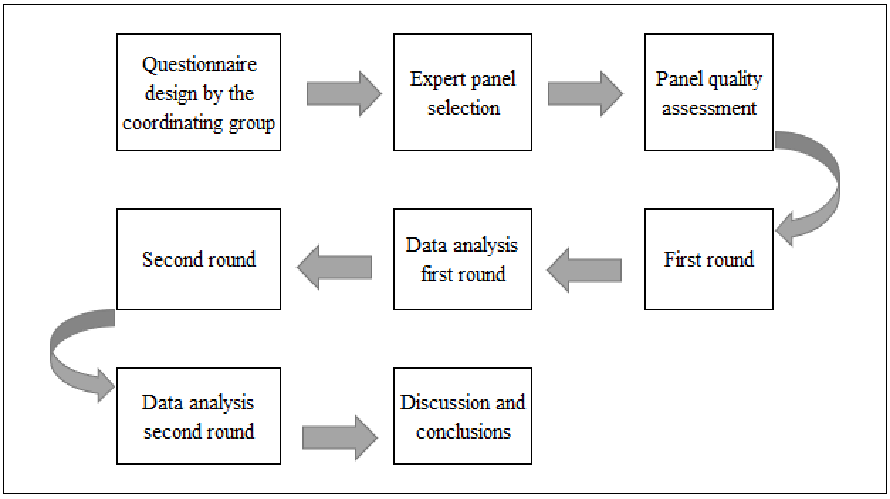


Fig. 4. Delphi method phases

3.1. Questionnaire design

The coordinating group established the objective to identify the degree of consensus among experts on the components and attributes involved in the construction of a design pattern, therefore, this led to the design of two rounds in our Delphi study.

In the first round, the experts replied to an open-ended questionnaire to identify the language used in the pattern design for learning, and in turn the elements that comprise them. This information made it possible to construct the questionnaire for the second round.

The second round began with the socialization of the results of the previous round. Subsequently, the experts applied an instrument in which they were asked to assign the attributes to components and process groups.

The questionnaires for rounds one and two were completed using Google forms and sent to the experts by e-mail. In addition, the following settings were applied: a) Allow access by collecting e-mail addresses; b) Restrict editing of responses; c) Limit to one response.

3.2. Panel of experts

This stage consists of selecting the group of people who will carry out the evaluation or issue an opinion focusing on the deeper levels of a particular aspect. The proposals of Cabero & Llorente (2013), suggest a number ranging from 15-50; Sanromà-Giménez et al. (2021), between 1015; López-Gómez (2018) indicates that their number should not be less than 12.

As seen above, there is no consensus on the number of experts in the literature. However, studies show that a number of more than 12 participants is sufficient to stabilize the results if the participating experts have homogeneous knowledge of the subject under study (Ifenthaler et al., 2021).

Initially, the coordinating group proposed a pre-selection of experts in three phases. The first phase began with the identification of experts whose professional profile referred to their participation in the scientific committees of congresses related to educational technology, e-learning, distance education, etc., as well as the editorial boards of educational technology journals. This phase concluded with the identification of a group of 120 potential experts.

Subsequently, in the second phase we developed an expert biogram (Cabero & Llorente, 2013; García-Ruiz & Lena-Acebo, 2018). This allowed us to collect information on: a) Years of experience; b) Institution of higher education where he/she works; c) Publications related to learning design patterns; d) Training activities related to learning design patterns; e) Research experience related to learning design patterns.

Finally, the result of the biogram made it possible to select 80 potential experts to whom an invitation was sent by e-mail. This invitation contained the purpose of the study and a generalized description of learning design patterns. In a period of two weeks, 18 experts responded and expressed their availability.

3.3. Panel quality assessment

Initially, the suitability of the experts in the topic of study was evaluated by applying the expert competence coefficient K, which has been successfully applied in several studies (Cabero-Almenara et al., 2020; Mengual-Andrés et al., 2016; Sanromà-Giménez et al., 2021; Zartha Sossa et al., 2017).

The expert's competence coefficient is calculated using the formula $K = \frac{1}{2}(K_c+K_a)$, where K_c is the expert's "knowledge coefficient" on the research topic and

Ka is the "argumentation coefficient" or the sources of criteria used by the expert. The value of Kc is obtained from the expert's self-assessment on a scale from 0-10, multiplied by 0.1. On the other hand, the value of Ka is derived from the expert's self-assessment of the different sources of argumentation on which he bases his expertise, such as theoretical analysis of the subject, professional experience, participation in research projects, among others. Table 1 shows the results obtained by the 18 experts.

Table 1
Expert competence coefficient K for each expert

Expert	Country	Kc	Ka	K
1	Germany	0.9	0.95	0.92
2	Canada	0.5	0.8	0.65
3	Colombia	0.8	0.8	0.8
4	India	0.9	0.85	0.87
5	Spain	0.8	0.8	0.8
6	Spain	0.9	1	0.95
7	Colombia	0.9	0.95	0.92
8	Colombia	0.8	0.85	0.82
9	Argentina	0.4	0.6	0.5
10	China	0.8	0.85	0.82
11	Spain	0.8	0.9	0.85
12	Spain	0.9	1	0.95
13	Colombia	0.9	0.8	0.85
14	United States	0.8	0.8	0.8
15	United States	0.6	0.7	0.65
16	United States	0.7	0.7	0.7
17	Bolivia	0.8	0.8	0.8
18	Taiwan	0.9	0.9	0.9

Based on the results of the expert competence coefficient, the final group were confirmed by 14 experts. Table 2 shows the profiles of the participants.

Table 2
Profiles of the 14 experts participating in the study

Item	Profiles of the experts	Frequency
Gender	Female	8
	Male	6
Educational level	PhD	13
	Master's degree	1
Country of the university institution where the expert has an employment relationship	India	1
	Taiwan	1
	Spain	1
	Germany	1
	China	1
	United States	1
	Colombia	4
	Bolivia	1
Areas of professional experience	Educational technology, e-learning, distance education, higher education.	

3.4. Data analysis

The answers obtained in the first round were exported to NVivo (version 12), a qualitative data analysis software (Martin et al., 2015), which allows managing the answers to open-ended questions and coding the data. This process was developed to analyze content, search in the elements provided by each expert, categories, similarities in the text fragments and frequencies (Reguant-Álvarez & Torrado-Fonseca, 2016).

The analysis method used was inductive coding without preset code sets (Weinberg et al., 2020; Xu & Zammit, 2020). This approach allowed us to be open to all the answers provided by the experts and, therefore, to decrease the bias generated by the preconceived ideas and opinions of the researchers during the data analysis process.

The data obtained in the second round were statistically processed with SPSS Estatistics 19, in order to assess the degree of consensus among the experts. This can be understood as a measure implemented to identify convergence among the experts' opinions. The literature review shows that there is no single way of estimating consensus (López-Gómez, 2018); therefore, this led us to opt for using relative frequency, since it is accepted by the technique itself. This measure involves defining consensus in terms of the occurrence of individual estimates (Reguant-Álvarez & Torrado-Fonseca, 2016).

Considering the above, three rules based on the type of content were developed to measure the degree of consensus (see Table 3).

Additionally, stability between rounds was excluded from the study, due to our concern for having the same group of experts throughout the process. Admittedly, this variation in the Delphi method can generate limitations, but it does not mean that it is far from being a process with systematic, explicit and ethical methods (Reguant-Álvarez & Torrado-Fonseca, 2016).

To ensure anonymity, each expert response was coded as EXP followed by a number. This number was assigned according to the order in which the first round was completed.

Table 3
Rules for assignment of attributes to each component and process group

Consensus level	Parameter (*h*: Relative frequency)
Agreement (A)	$h \geq 64.3\%$
Disagreement (D)	$h \leq 35.7\%$ or [2-3] component/process at neutral level
Neutral (N)	$35.7\% \leq h \leq 64.3\%$ if there is only one component/process in this range

4. Results

Before describing the results, it is necessary to specify that the double round was developed by the same group of experts. This allowed the experts in the first round to provide a detailed description of the terminology used for pattern construction, rather than a general review of the subject. Subsequently, the continuity of the group allowed them to explore the responses of other experts and to review their own opinions in order to reach a consensus on the language of pattern design. This way of organizing the rounds in the Delphi method has provided reliable and replicable studies (Pinto-Santos et al., 2022).

4.1. First round

Question one: In the search for a standardized language, we would like to know what terms you have used to name the phases or general architecture when building design patterns for learning. (You may mention several).

The code that appears repeatedly is components (*n* = 7), followed by processes (*n* = 4). Fig. 5 shows the overall results.

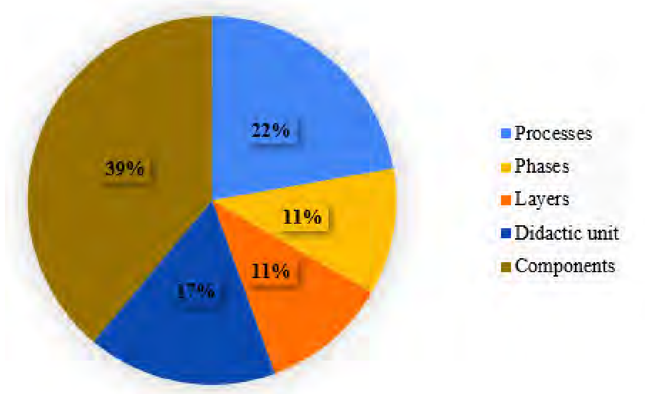
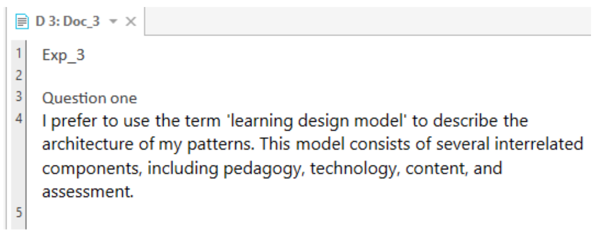


Fig. 5. Terms used to denote the architecture of a learning design pattern

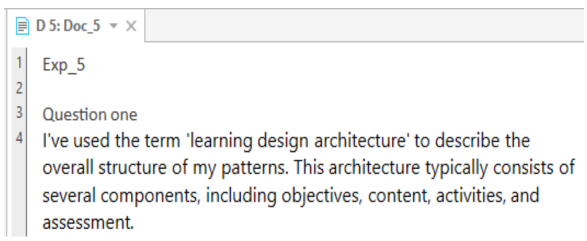
As can be seen, the component code is the first category to emerge. Expert opinions confirming the finding are presented below (see Fig. 6):


D 3: Doc_3
Exp_3

Question one
I prefer to use the term 'learning design model' to describe the architecture of my patterns. This model consists of several interrelated components, including pedagogy, technology, content, and assessment.

Fig. 6. Exp_3 answer

In the same vein, it is presented below (see Fig. 7):


D 5: Doc_5
Exp_5

Question one
I've used the term 'learning design architecture' to describe the overall structure of my patterns. This architecture typically consists of several components, including objectives, content, activities, and assessment.

Fig. 7. Exp_5 answer

Question two: Based on the previous answer, mention which are the elements that make up each of the phases or architecture of the design pattern for learning that you have built. (You may mention several).

In this question we understand that experts can use a broad lexicon to describe the elaboration of learning design patterns. Therefore, in order to achieve inductive coding, it was necessary to perform the following phases: Semantic word representation, word similarity table and cluster representation. The above succeeded in preserving the semantic meanings manifested by the experts, to intuitively reveal the general themes (Xu et al., 2016).

4.1.1. Semantic representation of words

The input data to develop the semantic representation of words corresponds to the word frequency query implemented in the Nvivo software. Initially, it was not necessary to decompose the text, since we had sentences that mostly did not contain empty words; however, to refine this step we used words with a length greater than five. Also, it was necessary to apply a filter to identify the 100 words with the highest frequency.

This led to obtaining the word cloud. Fig. 8 shows the fragmentary information of the text content in original language, identifying mainly the words: learning, design, objectives, evaluation, contents, etc.

4.1.2. Word similarity table

As it was necessary to perform an in-depth analysis, a phase called word similarity table was implemented. Here, co-occurrence rules were applied to discover and group strongly related concepts within the text. The main rule was that when concepts appearing together were found in the text, this co-occurrence reflects an underlying relationship that is likely to be valuable for category definitions (see Table 4).

Fig. 8. Semantic word representation

Table 4
Word similarity table (n = 100)

Word	Counting	Similar words
Instructional design	26	Designed, design, instructional design, instructional design, model
Learning	25	Learnings, learning
Assessment	16	Assessable, self-assessment, feedback
Description	16	Description, characteristics, definition
Objectives	15	Objectives, purposes
Resource	13	Resources
Final result	13	Deliverables, final results, completion
Clustering	13	Clustering, articulation, support, cooperation
Unit	12	Units, topics, homework
Criteria	11	Criteria, factors, conditions, principles
Activity	10	Activities, homework, deliverables
Content	9	Contents
Phase	9	Phases, process, processes
Formative modality	9	Formative, formative, modality, face-to-face, virtual
Implementation	9	Execution, application, construction, processing
Sequence	8	Sequences, itinerary
Start	8	Initial, issuance, rationale, proposal, definition
Competence	7	Competencies
Element	7	Elements, component
Educational stakeholder	7	Student, author, people, teacher
Plan	7	Planning, planning, strategy
Didactics	6	Didactic, didactics
Context	6	Context
Time	6	Times, calendar, timing
Material	6	Bibliography, webgraphy, materials
Program	5	Program
Pedagogical	4	Pedagogical
Rubric	4	Rubric
Metrics	4	Metrics, level, quantitative, monitoring, control
Tool	3	Tool
Problem	3	Problem
Organization	3	Organization
Analysis	2	Analysis
Curriculum	2	Curriculum
Teaching	2	Teaching
Management	2	Management
Solution	2	Solution
Technology	2	Technology, Technologies

4.1.3. Cluster representation

From the text segments organized in the table of word similarity, the representation of clusters was developed using the NVivo software. This phase made it possible to identify the bi-spatial dispersion of the variables, considering that homogeneity is preserved within each cluster and, on the other hand, the difference between clusters. The word similarity clusters presented in Fig. 9 in original language shows a partition into similar groups, revealing a possible coding.

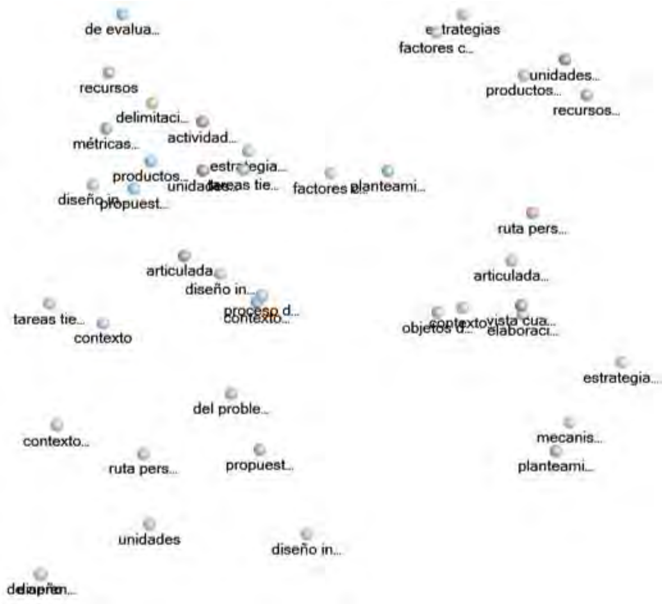


Fig. 9. Word similarity clusters

For a better reading of these results, a hierarchization of the cluster was implemented by means of a dendrogram. The diagram initially shows two groups from left to right; however, this number depends on where we cut the dendrogram according to criteria based on the objectives pursued by the research (Belzunegui et al., 2012). Through the process of in-depth review of the responses of the experts, the research team decided to place the cut of the dendrogram in the last branch, for better understanding (see Fig. 10).

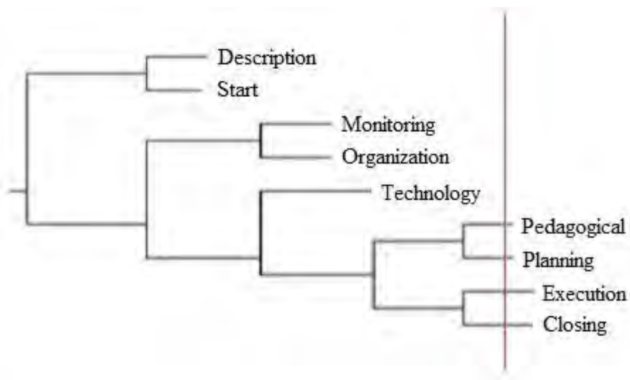


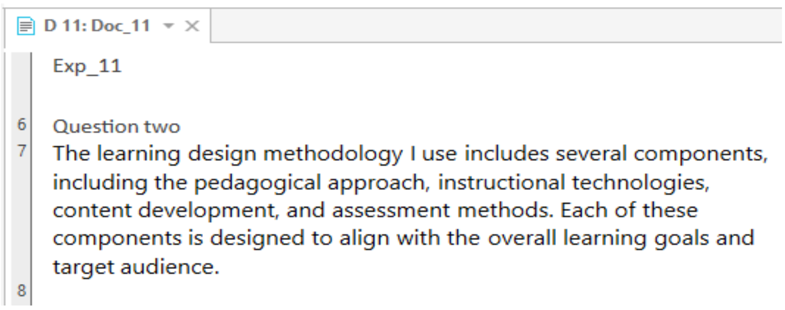
Fig. 10. Dendrogram: Hierarchical clustering

Drawing on the research objective, 32 units of meaning relevant to the construction of design patterns for learning emerged, which in turn are classified into three categories. Table 5 shows the coding scheme, the product of reading our data, analyzing the indexed word frequency list using the Nvivo software counting tool, and interpreting each meaning unit within the clusters.

Table 5
Coding scheme

Attributes	Components	Process groups
Model name	Descriptive	Start
Model metadata	Pedagogical	Planning
Training modality	Organizational	Execution
Model source	Technological	Monitoring and control
Financial resources		Closing
Problem situation		
Analysis		
Solution		
Context		
Consequences		
Related models		
Learning theory		
Learning objects		
Formative level		
Activity modality		
Software		
Teacher’s technical resources		
Learner’s technical resources		
Flexibility		
Learning assessment		
User assessment		
Objectives		
Stakeholders		

Initially, the category “attributes”, composed of 23 codes, emerges from a process of constant comparison within the text fragments provided by the experts in this round. The attributes make it possible to identify features of interest and extensive information on the design patterns for learning. An example of the above can be seen in the following text fragment (see Fig. 11):


D 11: Doc_11

Exp_11

6 Question two

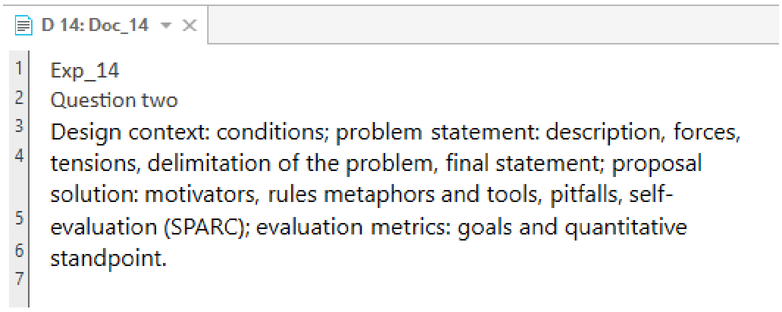
7 The learning design methodology I use includes several components, including the pedagogical approach, instructional technologies, content development, and assessment methods. Each of these components is designed to align with the overall learning goals and target audience.

8

Fig. 11. Exp_11 answer

Here is another expert’s opinion that is linked to a description expanding on the “attributes” that make up the design patterns for learning (see Fig. 12).

The name of this category had already been used in the works of Dehbozorgi et al. (2018), González (2012), Goodyear (2005), Gros et al. (2016), Iacob (2011), Martínez García (2009), Philip (2018), Jiménez (2009), and Rolf et al. (2019).


D 14: Doc_14

Exp_14
Question two
Design context: conditions; problem statement: description, forces, tensions, delimitation of the problem, final statement; proposal solution: motivators, rules metaphors and tools, pitfalls, self-evaluation (SPARC); evaluation metrics: goals and quantitative standpoint.

Fig. 12. Exp_14 answer

The analysis of the text fragments revealed that the descriptive, pedagogical, organizational and technological codes were used by the experts to conglomerate different attributes that make up the architecture of the design pattern for learning. Fig. 13 shows the network of connections between the aforementioned codes (codes in yellow), and the relationships that emerge between them.

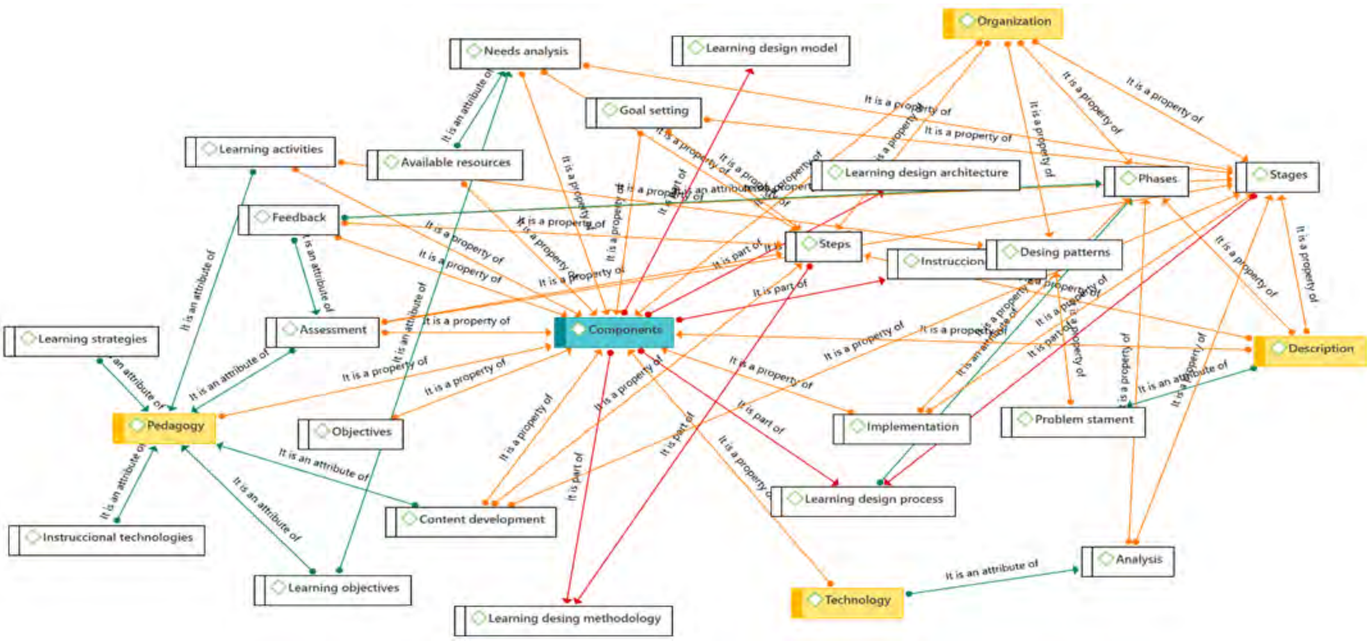
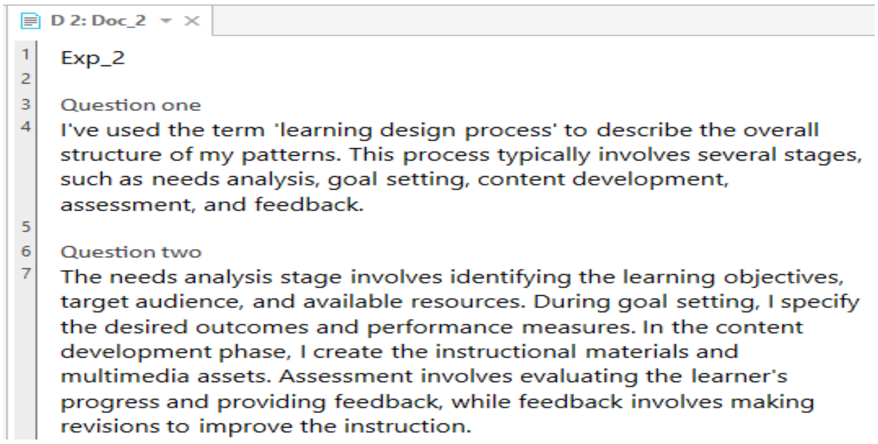


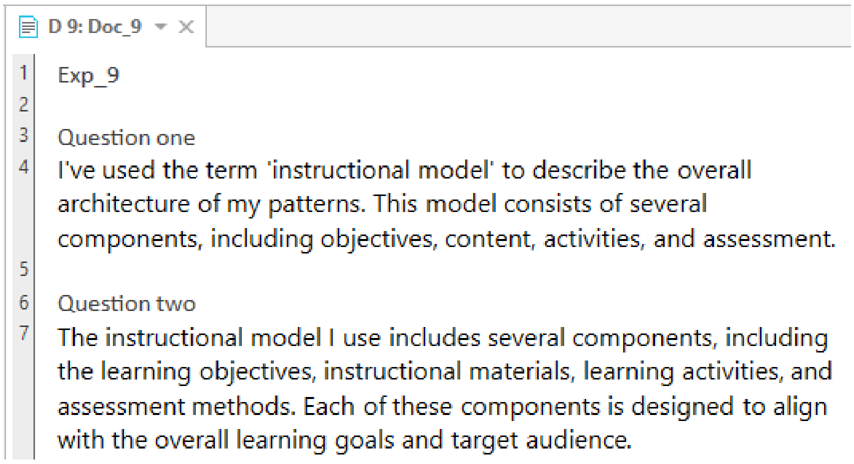
Fig. 13. Codes associated with the component category that group most of the attributes

As for the "descriptive" code, in the majority of the fragments of question one, the experts use the expression "describe the general structure" to extend the information about the content of the pattern. This leads to the conclusion that patterns require a descriptive component that includes their main characteristics. In the same way, the code "pedagogical" is mentioned to group together numerous didactic and instructional aspects required by the pattern. Next, the "organizational" code appears, implicitly used by the experts to relate aspects of learning classification, activities and their relationship with the training modality. Finally, the "technological" code conglomerates the definition of the technical and technological requirements for the use of the patterns, as well as the necessary competencies of the teacher and the student. An example of this can be seen in the following answers in Fig. 14 and 15:


D 2: Doc_2

1 Exp_2
2
3 Question one
4 I've used the term 'learning design process' to describe the overall structure of my patterns. This process typically involves several stages, such as needs analysis, goal setting, content development, assessment, and feedback.
5
6 Question two
7 The needs analysis stage involves identifying the learning objectives, target audience, and available resources. During goal setting, I specify the desired outcomes and performance measures. In the content development phase, I create the instructional materials and multimedia assets. Assessment involves evaluating the learner's progress and providing feedback, while feedback involves making revisions to improve the instruction.

Fig. 14. Exp_2 answer


D 9: Doc_9

1 Exp_9
2
3 Question one
4 I've used the term 'instructional model' to describe the overall architecture of my patterns. This model consists of several components, including objectives, content, activities, and assessment.
5
6 Question two
7 The instructional model I use includes several components, including the learning objectives, instructional materials, learning activities, and assessment methods. Each of these components is designed to align with the overall learning goals and target audience.

Fig. 15. Exp_9 answer

The category "process groups" places interrelated rules, actions and activities that enable the design pattern for learning to be obtained. These concepts emerged as the experts' described moments in which input requirements, information processing, monitoring and deliverables associated with the elaboration of the design pattern for learning were logically placed. The process groups allow the establishment of functional relationships (rules) between attributes and components.

Initially, the research team made the decision to think about the name of the category, based on the concept of "process". In this regard, Galván (2013) mentioned that: "a process is a set of interrelated actions and activities performed to obtain a predefined product, result or service" (p. 692), which accurately characterizes our finding. Subsequently, the experience of the research team in project management, led us to make a projection of the process groups defined in the guide of the fundamentals for project management (PMBOK Guide) / Project Management Institute (PMI) (Project Management Institute, 2017), towards the implemented coding system.

Other elements that supported our decision are related to the application of design patterns in the field of project planning (Martínez García, 2009), the design patterns by management levels (Salinas et al., 2006), the Domain Ontology for Project Knowledge Management (Sareminia et al., 2016) and the concordance that exists between the purpose of the PMI methodology (Project Management Institute, 2017) and the purpose of design patterns (Goodyear & McAndrew, 2013).

In view of these results, the following groups of processes were implemented:

- Start processes: Processes performed to define a new learning pattern or reuse of an existing one. Here they are identified (e.g., requirements, scope, objectives, and stakeholders).
- Planning processes: Processes required to design activities, resources and quality assessment in the design of a pattern for learning.
- Execution processes: Processes performed to complete the work defined in the plan for the design of patterns for learning, in order to satisfy its requirements.
- Monitoring and control processes: Processes required to track, analyze, and regulate the progress of the design of patterns for learning.
- Closing Processes: Processes carried out to formally complete or close the learning pattern design.

4.2. Second round

The results of the second round allowed the assignment of attributes to each component and group of processes. Initially, the attributes considered were obtained from the opinion of the set of experts in round one, together with others that emerged from the literature review. In total, 23 attributes used in the design of patterns in the e-learning modality were identified.

Table 6 shows the frequency count of the assignment of attributes to each component. In this sense, in the degree of agreement (A), they belong to the descriptive component (n = 4), pedagogical component (n = 8), organizational component (n = 5) and technological component (n = 3).

It should be noted that there are three groups of high scores in the degree of consensus agreement (A). Initially, the attributes with a level of agreement of 100% (n = 2) are identified, assigned to the pedagogical and technological components. Next are the attributes with a rating of 92.9% (n = 6), with a high frequency for the organizational component. Subsequently, there are attributes that report a level of agreement of 85.7% (n = 6), with the descriptive component being the one with the highest concentration of attributes. However, it is worth mentioning that there is a fourth group with ratings that reach a level of agreement of 78.6% (n = 6), located within the range of the degree of consensus, and whose component that groups the most attributes is the pedagogical component.

Based on this organization of the attributes, it is possible to think that the allocation is unequal, given that the pedagogical component contains 33.7%. From this circumstance it is proper to say that the knowledge developed by the teacher is adequately represented in the pedagogical design (Laurillard, 2013) and there is an emphasis of e-learning design from usability to pedagogy (Hadzhikolev et al., 2019). The above, may produce a bias in the adoption of pattern language and its use for grouping attributes.

Finally, the results show that there was a disagreement and concurrence for the related models attribute, due to a dispersion of frequency in the descriptive and pedagogical components.

Table 6
Frequency count for the assignment of attributes to each component according to the experts' criteria in round 2

Attributes	Descriptive	Pedagogical	Organizational	Technological	Consensus
Model name	85.7	7.1	7.1	-	A
Model metadata	64.3	-	28.6	7.1	A
Formative modality	85.7	-	14.3	-	A
Model source	50.0	28.6	7.1	14.3	N
Economic resources	7.1	-	92.9	-	A
Problem situation	7.1	78.6	7.1	7.1	A
Analysis	21.4	64.3	14.3	-	A
Solution	7.1	78.6	7.1	7.1	A
Context	7.1	-	92.9	-	A
Consequences	14.3	64.3	14.3	7.1	A
Related models	42.9	35.7	7.1	14.3	D
Learning theory	7.1	92.9	-	-	A
Learning objects	7.1	71.4	7.1	14.3	A
Educational level	7.1	-	92.9	-	A
Modality of the activity	7.1	-	92.9	-	A
Software	-	-	-	100	A
Teacher's technical resources	-	-	14.3	85.7	A
Student's technical resources	-	-	7.1	92.9	A
Flexibility	7.1	7.1	85.7	-	A
Learning assessment	-	100	-	-	A
User rating	-	28.6	50.0	21.4	N
Objectives	14.3	85.7	-	-	A
Stakeholders	85.7	7.1	7.1	-	A

Table 7 shows the attributes assignment for each group of processes. Initially, for degree of agreement (A), 6 attributes were assigned to the start process, 8 attributes to the planning process, 1 to the execution process, 2 attributes to the monitoring and control process and 1 to the closing process. In line with the rules proposed by the research team for the assignment of attributes, the experts reached disagreement in the assignment of 3 attributes. Finally, the attributes of learning theory and flexibility obtained a neutral level of consensus, given the dispersion of the relative frequency in two or three process groups.

About the scores in the degree of consensus agreement (A), it should be noted that attributes with a level of agreement of 100% (n = 2) are identified, assigned in the start process and planning groups. However, and no less important is the significant assignment of the other attributes in this same degree of consensus (n = 16), whose ratings exceed 64.3%.

In contrast to the concentration of the scores obtained in the components, it can be seen that there is a greater dispersion of the relative frequency for the attributes in each group of processes. An explanation for this result lies in the decision made by each expert at the moment of executing a process, understanding that its fulfillment does not imply a systematic action by phases to achieve the design of patterns for learning.

Table 7
Frequency count for the assignment of attributes to each group of processes according to the experts' criteria in the 2nd round

Attributes	Start	Planning	Execution	Monitoring & control	Closing	Consensus
Model name	71.4	28.5	-	-	-	A
Model metadata	64.3	28.5	7.1	-	-	A
Formative modality	28.5	64.3	7.1	-	-	A
Model source	71.4	14.2	7.1	7.1	-	A
Economic resources	35.7	64.3	-	-	-	A
Problem situation	35.7	50	14.2	-	-	D
Analysis	21.4	64.3	-	7.1	7.1	A
Solution	-	28.5	35.7	7.1	28.5	D
Context	64.3	28.5	7.1	-	-	A
Consequences	-	14.2	21.4	64.3	-	A
Related models	21.4	64.3	7.1	7.1	-	A
Learning theory	28.5	57.1	14.2	-	-	N
Learning objects	21.4	-	78.5	-	-	A
Educational level	28.5	64.3	-	7.1	-	A
Modality of the activity	-	100	-	-	-	A
Software	14.2	42.8	42.8	-	-	D
Teacher's technical resources	-	64.2	21.4	14.2	-	A
Student's technical resources	-	64.2	21.4	14.2	-	A
Flexibility	14.2	50	28.5	7.1	-	N
Learning assessment	-	14.2	-	64.2	21.4	A
User rating	7.1	-	-	28.5	64.2	A
Objectives	71.4	28.5	-	-	-	A
Stakeholders	100	-	-	-	-	A

In summary, Fig. 16 and 17 show the graphical representation of the distribution of attributes to each component and process group.

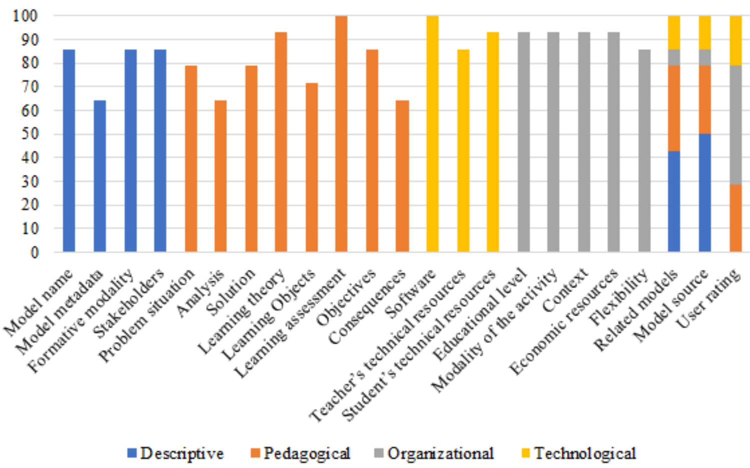


Fig. 16. Attributes assigned to each component (n = 20), unassigned (n = 3)

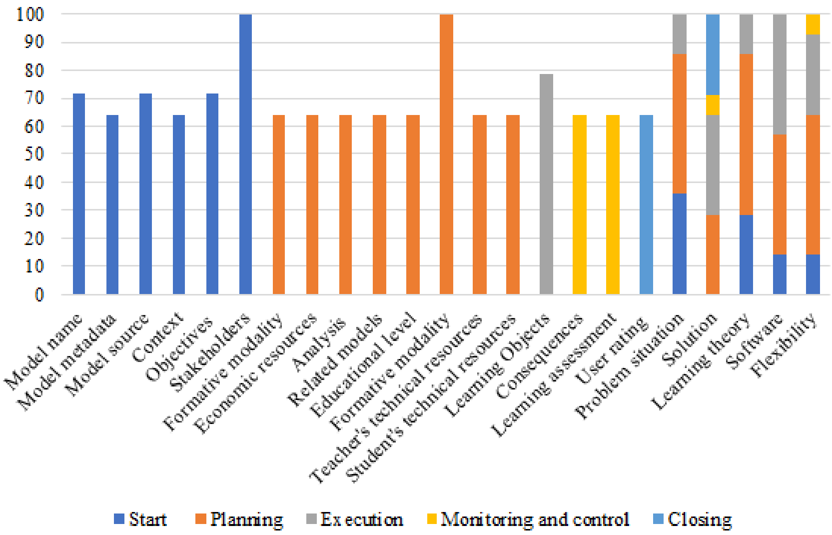


Fig. 17. Attributes assigned to each process group (n = 18), unassigned (n = 5)

5. Discussion

To begin with, the literature review allowed us to identify that we are faced with different pattern languages that arise from each area of knowledge, based on the logic of their own instances, and simultaneously, in other areas that seek to solve problems. Assuming this, it should be specified that we have a dynamic formal pattern language. Hadzhikolev et al. (2019) and Gros et al. (2016), conceived the above in their research and concluded on the absence of a standardized format of language, however, in view of the results there is a general domain that delimits the key elements for its architecture. Zapata Ros (2011) and later Seoane & García-Peñalvo (2014) specified these elements, indicating that formal and informal languages, as happens with pattern languages, are composed of grammatical rules of morphological, semantic and syntactic character. In his work, this metaphor explains how their components are created (morphology), what meaning they possess (semantics) and how they relate to each other (syntax).

Based on the above, this paper has preferred to use a simpler terminology (attributes, components, process groups), consistent with the natural discourse of the expert set and the architecture of the patterns reported in the literature review.

In this context, the use of expressions (e.g., phases, layers, and components) was common, the latter being the predominant one to describe the pattern architecture. Therefore, in our opinion, these terminological analogies respond, in the first place, to the discourse in a natural language determined by instances of the area, its rules and the problem to be solved. Likewise, their inclusion is related to an influence of software engineering applied to the reuse of the solutions created in this field (Buitrago et al., 2021). In our reflection, the challenge lies in identifying the effect of the implementation of the semantic varieties reported, applied in the different educational modalities.

As for the attributes, their function is to characterize the elements necessary for the construction of the design pattern and, in turn, to establish functional relationships between the descriptive, pedagogical, organizational, and technological components.

Compared to those reported in other studies (Hadzhikolev et al., 2019; Salinas et al., 2006), their number is lower. In this regard, we find that the portfolio will be limited by the structure of the problem space addressed, probably obtaining larger or smaller design patterns.

The results of assigning attributes to the components showed that 3 were left out of the distribution. Here we understand that the attributes and their assignment are not absolute, but for their better understanding in a given pattern language, they can be structured and formalized according to the pedagogical ideas of the developers of the learning activities. The above, was mentioned by Goodyear & McAndrew (2013) when stating that, "Design patterns are often written, shared, critiqued and refined through a broad collaborative process." Therefore, the unassigned attributes in this research, or a new portfolio configuration, can be refined in future research, so that a pattern language transferable to patterns from different pattern languages can be established and made available in various cases.

On the other hand, a design pattern architecture consisting of 4 components and 5 process groups has been obtained. This type of semi-structured pattern format presents an adequate balance within its organization (it satisfies the definition of a formal pattern language, it guides the user to design other patterns, the pattern instances belong to the same formal pattern language, the pattern language is consistent and shareable) that characterizes the design, according to the research of Laurillard (2012), Bafandeh et al. (2017) and Hadzhikolev et al. (2019). Specifically, a broader relationship of elements has been incorporated, to those traditionally reported (context, problem, solution and illustrative diagram) in the works of Alexander (1979) and Goodyear (2005). In addition to the above, this language based on attributes, components and process groups synthesizes a path for future studies and avoids starting from scratch.

This discussion would be incomplete if it ignored the implications of linking the category process groups to the pattern language. To begin with, the natural function of process groups is to describe rules, to logically place interrelated actions and activities that allow obtaining a design pattern for learning. Therefore, with their incorporation we do not intend to describe the phases of the design of a pattern, but to propose a category that structures the relationships between the categories attributes and components. This has been called the "structuring principle" in other studies on design patterns. Goodyear & Yang (2009) define it as: "is what organizes a set of patterns into a whole (a language)" (p. 179). However, these initial results need to be corroborated in further studies in different contexts of pattern design.

Likewise, evidence of the application of process groups in the educational sector is found. Bayona et al. (2018) presents work on subject management, research project management, development of educational material and execution of educational self-assessment. This indicates that the PMI framework for project management is not limited to industry; however, there is a risk of resorting to specific training on this topic, in order to obtain better results in the development of design patterns for learning.

Another aspect that we have analyzed is related to the link between the elements of project management and the emerging categories. For this, we considered the factors decision of the research team and similarity in the descriptors: purposes and life cycle. For the first element, it should be noted that the decision to project the names of the project management process groups into the codes was not a priori. This responded to a process based on the experience and consensus of the research team, a key situation for designing patterns (Goodyear, 2005; Laurillard, 2013; Zapata Ros, 2011).

Regarding the descriptors, the literature allowed identifying that both share in their purpose the principle called "good practices to implement recurrent solutions". The above was proposed in pattern design by Jiménez (2009), Seoane & García-Peñalvo (2014) and Goodyear & Yang (2009); and for the PMI methodology in (Bayona et al., 2018; Project Management Institute, 2017; Sánchez-Arias & Solarte-Pazos, 2010). This implies that they can be implemented many times, without ever doing it the same (Laurillard, 2013). In the same vein, the descriptor "life cycle" in both contexts implies that their design is usually a process of several iterations around a cycle of articulation with the design objectives (Seoane & García-Peñalvo, 2014).

Finally, it was important to analyze the implications that the formalization of the proposed language will have for pattern designers (especially novices). Therefore, this proposal allows the union between theory and experience, drives innovation and creativity for pattern design supported by references to research literature.

6. Conclusions

In this article, we have outlined a methodology focused on identifying a language for organizing patterns, which helps researchers visualize an ecosystem for representing and sharing design experiences. It should be noted that the path to obtaining a pattern language for networked learning proposes a thorough and iterative work (Goodyear, 2005).

We share the idea that the development of patterns requires the generalization of solutions; therefore, it is necessary to make more dissemination of collaborative works that share experiences of good practices with the proposal that arises in this research. Likewise, we know that the portfolio of attributes, components or process groups may be broader due to the emergence of new patterns. This will lead to a consistent and sharable pattern language. However, this research represents a milestone built through a collaborative process around the pattern language for e-learning.

In conclusion, this study has important implications for educational researchers and practitioners, as it will help facilitate meaningful conversations between people with different professional backgrounds. First, the proposed language structure is recognizable to those with software/application development experience, allowing them to create more precise definitions of key educational processes and phenomena, thus reducing ambiguity and complexity in their interactions with educational specialists. Second, this approach provides the richness and flexibility that educators need to describe what is important without trivializing or over-formalizing. Third, by fostering a culture of an "ecosystem of attributes" that shape the pattern, it opens a path to open and adaptable solutions without imposing a rigid approach or language.

7. Limitations and future research

There are limitations in this study, the first is related to the application of the Delphi method. This method is a consensus technique; therefore, it was not possible to implement a third round in which the experts had the possibility of prioritizing the assignment of attributes to the components and process groups. There is also the possibility of subjective bias resulting from the interpretation of the qualitative results based on the suggested coding.

The second limitation was not applying questions to the experts about their knowledge around the absence of a relationship between patterns with design experience and practice. Therefore, we know that it is important to explore the various circumstances and limitations, (e.g., the time it may take to apply the proposed language, sense of confusion in not finding a common literature framework, absence of standardization, and studies assessing quality).

Author Statement

The authors declare that there is no conflict of interest.

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