Using patterns to design technology-enhanced learning scenarios

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Research on designing for learning is a field that has concentrated a lot of efforts in the context of technology-enhanced settings. This fact has demonstrated the need to represent learning scenarios using a more formal perspective.

This paper reviews some representation mechanisms which enable the systematic design of learning issues in technological settings, and proposes an approach that applies pattern notations in an effort to better understand and prepare for different learning context.

A case study is also described to show the application of these scenarios in a specific technology-enhanced setting for teaching computing curricula. This application is based on the use of digital ink technologies and demonstrates how patterns may be able to mediate between pedagogical and technical issues.

1. Introduction

The research on designing for learning is a field that has concentrated a lot of efforts, particularly, in a context of ongoing innovations in technology-enhanced settings. Such fact has pushed the need to represent learning design issues in a more formal view in order to face this changing context. The current work describes some representation mechanisms which enable the design of different learning issues in a systematic way and take into account the restrictions imposed by specific technological environments and products.

The interest to formalize or interpret different learning issues in a more methodical way comes from disciplines such as the Instructional Design (ID) or Instructional Systems Design (ISD) that provide systematic strategies and techniques in the design of teaching processes. Designing instruction has been addressed in technology-based settings (Rogers, 2002) and ID models have been used to produce tools which automate their application (Kasowitz, 2002). However, some limitations have been detected when automating instructional design because the complexity of learning scenarios (Spector & Ohrazda, 2003), especially, in such technical settings. In a parallel way, Learning Design (LD) deals with the need to guide and support teachers in the preparation of effective learning scenarios and specific tools called "pedagogical planners" have been developed to assist teachers in this goal (Masterman, 2008). Besides, LD adds an interesting feature that concerns the representation of teaching and learning issues, for example, to document them in some visual format (Agostinho, 2006). This feature allows instructors to share and reuse good learning practices but it also helps them to model and organize their tasks in a systematic way. The representation of teaching and learning issues is not only related to LD areas and there are multiple initiatives in the last years which have contributed to the modeling and documentation of these learning information items. Computer science and software engineering disciplines have promoted different notations and mechanisms in this context. Hypermedia models, ontology proposals, modeling languages, standard specifications or conceptual maps are some examples which are reviewed in the next section. These mechanisms provide several ways to represent learning issues in text or graphic format, using natural language or through a restricted vocabulary and differing in their formalization level or abstraction degree. Anyway, the crucial aspect is considering such mechanisms as "mediating artifacts which help practitioners to make informed decisions and choices to undertake specific teaching and learning activities" (Conole, 2008). Moreover, these mechanisms should help to mediate or connect pedagogical questions with technological-based solutions.

This work proposes the use of design patterns as "mediating artifacts" to represent technology-based learning scenarios. Patterns are a well-known notation to design different kinds of information items whose application is widely spread in Software Engineering disciplines. Patterns have been also used in other disciplines, including pedagogical and e-learning areas. Therefore, they seem a right mechanism to represent learning design issues in specific technology-enhanced settings enabling the connection between both sides.

The remainder of the work is structured as follows. The next section provides a general overview about several mechanisms and notations which have been formulated to represent different LD issues. The third section presents an approach to use patterns for designing learning in technology-enhanced settings. The fourth section describes the application of the introduced approach in a specific context based on digital ink technologies. Finally, some conclusions and further works are remarked.

2. Review of learning design notations

There are multiple kinds of mechanisms and notations which have been proposed to design different issues in pedagogical or instructional topics. This review does not intend to cover all the potential mechanisms to represent or model these issues but it tries to highlight those which have contributed to mediate between pedagogical and technological aspects. For instance, Nervig (1990) explored some of these mechanisms in the ID context and initiatives such as IDT (Merrill, 1996) or MISA (Paquette et al, 2001) proposed elements and languages for specifying instructional applications. Nevertheless, the formal specification of these applications and their components was usually disregarded (Wiest&Zell, 2001).

Educational hypermedia was one of the first mechanisms used to formalize the design and development of instructional applications in a systematic and widespread way. They were based on specific software engineering models such OOHDM (Schwabe & Rossi, 1995) or AHAM (De Bra et al, 1999) to produce educational products using UML diagrams (Papasalouros & Retalis, 2002) or other kind of graphical notations (Diaz et al, 2001). Buendía & Díaz (2003) proposed a hypermedia framework to manage educational contents conjugating instructional and technical issues. Hypermedia models and tools were adequate for designing specific educational applications. However, the fact they were based on graphical notations made them difficult to understand by non-computer literate users such as teachers or instructors.

Another type of mechanism (or artifact), traditionally applied to represent pedagogical and instructional issues, is the ontology which can be defined as "a specification of a conceptualization" (Gruber, 1992). Murray (1996) defined special ontologies for representing pedagogical knowledge and ontological modeling has been used for designing educational systems (Mizoguchi et al., 1997). Therefore, constructing ontologies in educational design is a well-known area with the advantage that explicit relationships between learning concepts help to infer or discover new knowledge from previous. For example, from the Bloom's objective taxonomy certain terms can be extracted to be linked with other learning concepts such as instructional needs or a task vocabulary (Conole, 2008). There are some references about using ontology notations in learning design (Knight et al, 2005), (Koper, 2006) but, in general, most of their application have been focused on modeling domain concepts or developing specific products such as ITS (Intelligent Tutor Systems). Nevertheless, the research on ontology notations has derived towards other interesting fields such as map specifications or educational modeling languages as powerful representation mechanisms in the LD context.

Modeling languages have been proposed in different areas and education was not an exception. Education modeling languages (also known as EMLs) were analyzed in the context of the "Workshop on Learning Technologies" project (CEN/ISSS, 2002) as a review of the multiple notations proposed to facilitate the description of pedagogic aspects involved in educational-learning processes (Koper, 2001). The different EML proposals were considered in order to produce a standard specification called IMS-LD (IMS, 2003) addressed to "support a wide range of pedagogies in online learning". This specification provides a generic neutral language that can be adapted to many different pedagogies but that feature is, perhaps, its main weakness because it is not trivial for instructors to "translate" their pedagogical view into this kind of specification. However, it is important to recognize the relevance of IMS-LD to build and share learning designs from the XML notation used to express such specification and there are multiple tools and platforms which support their processing. Moreover, UML diagrams have been provided to represent these learning design specifications using a graphical display. This notation was complemented with text narrative descriptions that contributed to a better understanding of the IMS-LD learning scenarios.

A more tailored way to represent LD issues in specific learning scenarios can consist in using map-based or any kind of simple graph notations. For example, concepts maps can be used to describe the 'best fit' strategy for designing an e-learning course (Adorni et al, 2009) under the particular lecturer view. Perhaps, that situation hampers the sharing of learning designs produced by different lectures but in a further step, this collection of map-based designs can be processed in order to get a common design template. Moreover, concept mapping can also be seen as a first step in ontology-building, and meanwhile, be used flexibly to represent specific learning designs adapted to technology-enhanced settings (Buendia, 2011). Mind-maps provide similar representation facilities and mapping tools can be deployed to generate LD templates from different case studies (Conole & Weller, 2008). A further step is based on the use of topic maps as an ISO standard whose aim is describing knowledge structures with XML encoding schemes that facilitate their processing. Topic maps have been applied in LD contexts (Adorni et al, 2008) and there are specific environments for authoring educational topic maps (Dicheva & Dichev, 2006).

In summary, there have been reviewed several mechanisms to represent LD issues. They range from highly structured and formal notations like hypermedia models, ontology notations or topic maps to semiformal mechanisms such as educational languages, concept or mind maps. Next section describes design patterns as an alternative representation tool which combines the flexibility of narrative textual-based representation techniques, the visualization capability of sketches or similar graphical displays and the ability to incorporate controlled vocabularies or ontology terms into their definition.

3. Learning design approach based on patterns

The current work introduces an approach to represent LD issues by means of design patterns. The use of patterns can be considered as a structured method of describing good design practices in different fields of expertise. Originally, design patterns were introduced by Alexander et al (1977) in architecture disciplines as "a careful description of a perennial solution to a recurring problem within a building context". This pattern notion has been adopted in other disciplines such as Software Engineering or Interaction designs. Furthermore, pedagogical patterns are recognized as efficient mechanisms to document good practices in teaching (PPP, 2005), including visual flow representations (Hernandez et al, 2007) and there are design patterns which have been proposed in e-learning contexts "as conceptual tools to support educational design" (Goodyear, 2005). Rohse, S., & Anderson, T. (2006) also justify the use of design patterns recognizing that learning is a complex process, particularly, when digital technologies in continuous change become a key component in this process.

Therefore, patterns seem a powerful mechanism to allow instructors and practitioners designing different learning issues related to items such as theoretical contents or laboratory activities in a certain technology-based educational context. The approach proposed in this work is based on promoting a "guide rather than prescribe" philosophy to apply patterns, focused on small-scale learning experiences and bounded to specific technology settings. Next subsections describe such approach to use design patterns which is structured into two main phases: (i) the *Preparation* of the target patterns and (ii) their *Deployment* in a specific context.

Preparation

In a first approach phase, a pattern language has to be chosen. Table 1 shows a summary of the language proposed to define patterns that fit the learning design philosophy aforementioned. This pattern language is mostly based in the original Alexandrian definition which is mainly narrative with some additional attributes and special features: i) the diagrammatic part is complemented with tags that specify particular concepts with a potential instructional purpose and ii) an extra field called *Keywords* that gathers some of the previous tags and other terms which characterize the learning scenario through the proposed pattern.

The second step consists in classifying patterns in several categories in order to facilitate their further detection, definition and processing. Figure 1 shows a map example that displays some basic concepts that can be part of a learning scenario in

Name	Pattern identifier
Context	Description of the learning scenario in which the selected pattern is applied
Problem	Overview about the learning or instructional requirements to be faced
Discussion	Explanation to motivate the addressed problem and its justification
Solution	Description of the way to apply technologies to solve the addressed problem
Diagram	Sketch to represent the solution in a graphical display including descriptive tags
Relationships	Links to other patterns which could be useful in the learning scenario design
Keywords	Links to other patterns which could be useful in the learning scenario design

Table 1: Pattern language for learning design

which a given pattern could be applied such as content resources or learning activities. These map concepts could be extracted from an educational ontology in order to improve their connection with pattern information items.

The concepts represented in Figure 1 can be distributed in four main groups: *contents, activities, interaction* and *assessment*. From this distribution, an initial pattern classification can be set up to organize them into the next categories:

- Content managers: composed by patterns that help practitioners to elaborate the didactic materials or resources by enriching the original contents with multimedia formats or adding annotations or signals to provide instructional hints that assist their teaching.
- Activity facilitators: include patterns which assist the instructor in the preparation of learning tasks based on "problem solving" techniques, or allow teachers to design seminars that contribute to discuss specific topics and improve their learning.
- Interaction enablers: contain patterns to support actions, maybe, not directly addressed to teach about a certain topic or acquire specific competencies. Such actions should encourage the student participation or enable their interaction with other students.
- Assessment producers: associated to patterns that allow teachers to elaborate different kind of mechanisms to assess the student performance or their behavior (e.g. multimodal assessment or formative vs. summative evaluation).

To finish the pattern preparation, these can be produced or defined considering different possibilities. In some cases, there is available a catalog of patterns according to different criteria (PPP, 2005) which can be applied in a straightforward way. The current work is focused on producing those potential patterns which can be useful in a specific technology-based educational

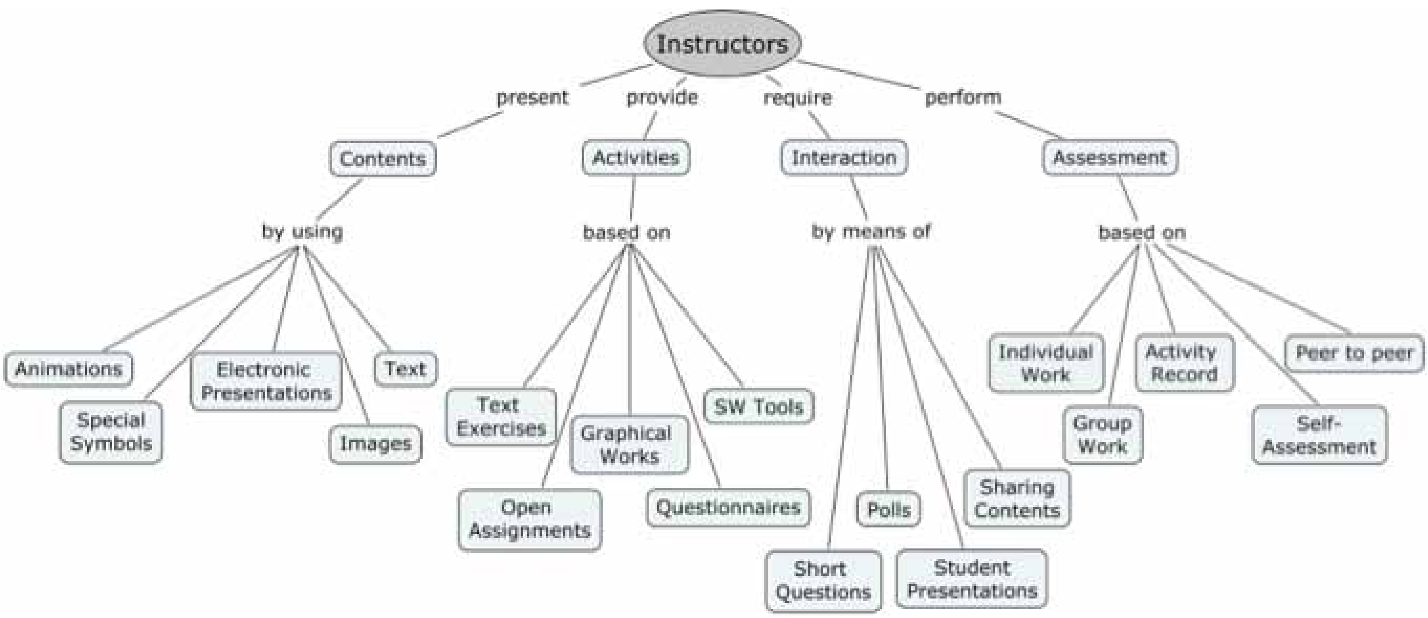


Figure 1: Instructional concept map in a learning scenario sample

setting (Buendía & Cano, 2006). There are some methods to detect or induce these learning patterns (Brouns et al, 2005) but the selected approach is based on the observation of learning scenarios in close disciplines and the detection of successful practices when certain technologies are involved.

Deployment

The pattern deployment is based on a well-known instructional design method called ADDIE (Molenda, 2003) which stands for *Analysis, Design, Development, Implementation* and *Evaluation*. The *Analysis* phase should gather those requirements relevant to the target learning scenarios such as instructional goals or learning objectives. Table 2 shows a list of requirements which could be assigned in the context of a revision of the Bloom's taxonomy (Anderson& Krathwohl, 2001) for Computing curricula. These examples of learning requirements contain actions that can be mapped to the components of a learning scenario such as the one represented in Figure 1. For instance, actions such "recognize the computer entities" or "implements a logical circuit" can be linked to display educational contents or perform academic activities in a learning scenario context.

Goal category	Pattern identifier
Remembering	Description of the learning scenario in which the selected pattern is applied
Understanding	Overview about the learning or instructional requirements to be faced
Applying	Explanation to motivate the addressed problem and its justification
Analyzing	Description of the way to apply technologies to solve the addressed problem
Evaluating	Sketch to represent the solution in a graphical display including descriptive tags
Creating	Links to other patterns which could be useful in the learning scenario design

Table 2: Potential learning requirements

The matching process between learning requirements and pattern information is the critical stage to select the right design pattern that should solve the stated need or problem and using the pattern categories defined in the *Preparation* phase. In this point, ontology notations can help to determine the terms or concepts to be searched in the pattern catalogue. The information contained in the pattern *Problem* attribute should also facilitate this matching process and other information items can be taken into account such as the *Context*, the *Discussion* or the *Keywords* attributes. This process is usually manual but it could be supported by a wizard tool or assisted by experts in the pattern management.

An advantage provided by design patterns is they are usually represented by sketches or diagrams easy to interpret by teachers who are non-computer literate. The pattern narrative structure also contributes to facilitate its systematic application and the inclusion of tags in the graphical display permits a better understanding of the *Solution* attribute description. The proposed approach also encourages explaining how specific technologies are applied in the context of the target pattern and detailed instructions either text or graphic-based should be incorporated in the *Solution* description. Then, such technological details could give support to the *Development* of the required LD component to elaborate certain learning resources from recommended multimedia formats or design activities exploiting the pattern potential. In a similar way, the *Implementation* phase has to address the particular conditions provided by the available learning platforms to accommodate those patterns which are implemented in such platforms. Eventually, the *Evaluation* step should check the pattern application in order to test if its application has been successful. In this case, instructional experts could evaluate this application by checking the matching between pattern sketches and teacher proposed solutions. The next section describes an application case to elucidate this deployment process.

4. Approach application

The aforementioned approach has been applied in a specific learning context based on the use of digital-ink technologies. Next subsections describe the context that enabled the proposed approach and the preparation and deployment of digital-ink patterns in this context.

Context

Patterns have been applied in a Higher Education context at the UPV (Universitat Politècnica de València). In particular, they were essayed in several courses of undergraduate Computing degrees, in an attempt to adapt these courses according to the Bologna Declaration guidelines. Some studies have been carried out over the last six academic years that reveal instructional problems such as: low participation and student interaction, pupils' lack of motivation, low class attendance rates, high course drop-out rates and eventually, poor students' performance. To deal with these problems, the UPV raised several educational innovation projects and one of them was granted by Hewlett Packard in the framework of the *HP Technology for Teaching Grant Initiative, Transforming Teaching and Learning through Technology* (HP, 2008). The central idea of this project was to exploit the potential of digital ink technologies to deploy a more interactive teaching and learning environment based on the use of Tablet PCs and similar devices.

Tablet PCs can be considered as traditional laptops including an LCD screen on which the user can write using a special pen. These devices rely on digital ink technology, where a digitizer can capture the movement of the pen and thus, allowing users to put data onto the screen in a natural way. Digital inking enhances the chances for active learning activities allowing actions such as handwriting, highlighting, marking, drawing, sketching or doodling. The project granted by HP equipped a special classroom with twenty Tablet PCs where several learning experiences were developed since the year 2009. The first experience was applied during the spring 2009 semester to a pilot group of *Computer Technology*, a core first-year Computing Engineering course. In the next semester, a new case was implemented in another pilot group of a core second-year course called *Data Structure and Algorithms* that in contrast with the first experience, could be considered a Computer Science subject rather different from the Computer Engineering course focused in the first experience. Nevertheless, the team in charge of the HP project realized that the design of the learning experiences based on digital ink technologies in both cases were very close and similar outcomes were obtained (Benlloch et al, 2010). During the course 2010-2011, new experiences were implemented in different Computing disciplines and analogous good practices were detected in their implementation.

Preparation of digital-ink patterns

The experiences aforementioned enabled to generate a catalogue of patterns based on digital-ink technologies (see Appendix A with some pattern samples classified by categories). The detection of good practices and satisfactory outcomes was crucial to start such pattern generation but another factor can be considered essential in this process. This factor was the need to conceptualize the potential of digital-ink technologies.

Figure 2 shows a concept map that displays some of the basic notions and actions related with the instructional use of "digital-ink" technologies. For instance, how "Handwritten inputs" can be used to introduce math special symbols or the ability to "Sketch" diagrams or "Highlight" information items. This con-

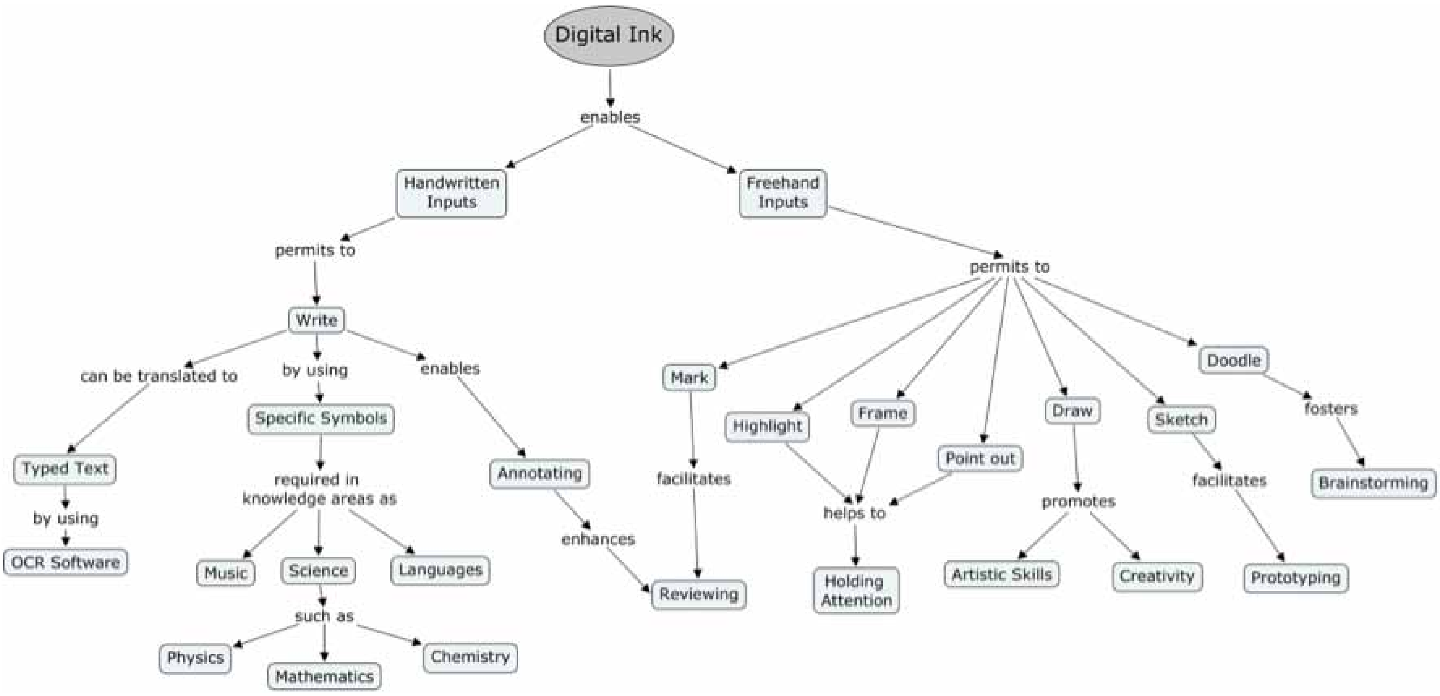


Figure 2: Concept map of digital-ink technologies

Name	Half-baked
Context	Teaching in a traditional classroom with electronic slides to display contents
Problem	Classroom sessions are boring and difficult to follow due to overloaded slides
Discussion	Slide-based teaching is a usual technique but these slides can evolve in a dynamic way allowing students to focus on the teacher's discourse
Solution	Instructor completes the prepared "half-baked" slide on the fly by means of instructional elements based on digital-ink technologies
Diagram	See Figure 3
Relationships	Light and shade, Augmented reality
Keywords	Electronic slides; classroom contents; understanding goal; adding explanations; framing concepts; drawing diagrams

Table 3: "Half-baked" pattern

ceptualization process was fundamental in the preparation of learning design patterns and it also contributed to select tags which characterize the *Keywords* attribute in the proposed pattern definition. Such process also enabled the connection with the learning scenario components mapped in Figure 1 (Buendía, 2011). One sample of digital-ink pattern in the *Content* category is called "Half-baked" and it describes the possibility to provide an initial version of a slide-based presentation whose main points can be complemented with additional annotations or drawings during the lecture.

Table 3 shows a short description of the pattern attributes according to their previous definition that includes bold terms remarking singular concepts. Figure 3 displays the diagrammatic representation of the pattern which contains red-labeled tags that refer instructional actions associated to the digital-ink technologies in the pattern context.

Deployment of digital-ink patterns

After their preparation, such digital-ink patterns were applied in the context of Computing degree courses to validate their use in real learning scenarios. Appendix B displays part of a questionnaire that was submitted to lecturers who wished to participate in these evaluation experiences in order to gather their instructional requirements. This questionnaire was based on a checklist format to ease the instructor's answers and its outcomes can be considered an essential tool in the *Analysis* step for the proposed approach. These answers contributed to detect the potential digital-ink patterns that could be useful for a set of instructors who taught a wide range of computing disciplines. Moreover, some instructor's answers were analyzed and their interpretation leads to advise these instructors against the use of digital-ink technologies in their teaching activities. In this analysis process, the matching between learning requirements and pattern possibilities was manually performed.

After this *Analysis* stage, selected instructors participated in several experiments on the proposed patterns in their courses. These experiments consisted in the elaboration of a real pattern sample implementation by each instructor in a specific learning scenario using the pattern sketch as a template guide. For instance, Figure 4a shows an example of pattern application in a Computer Technology subject. This example corresponds to

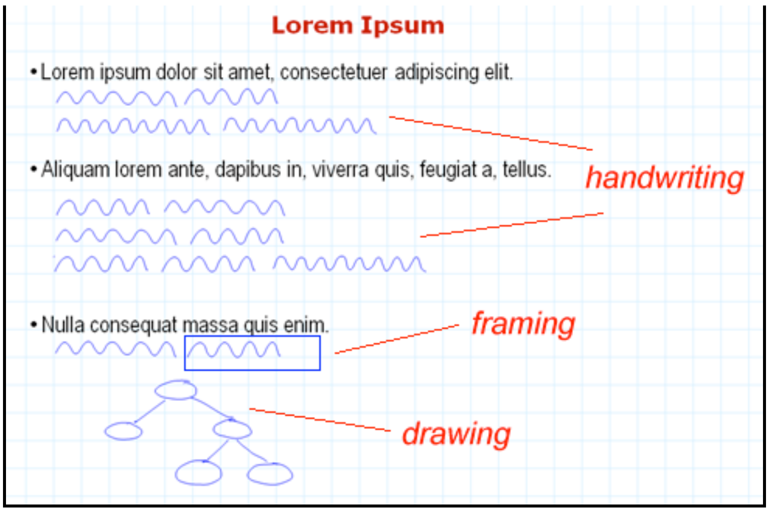
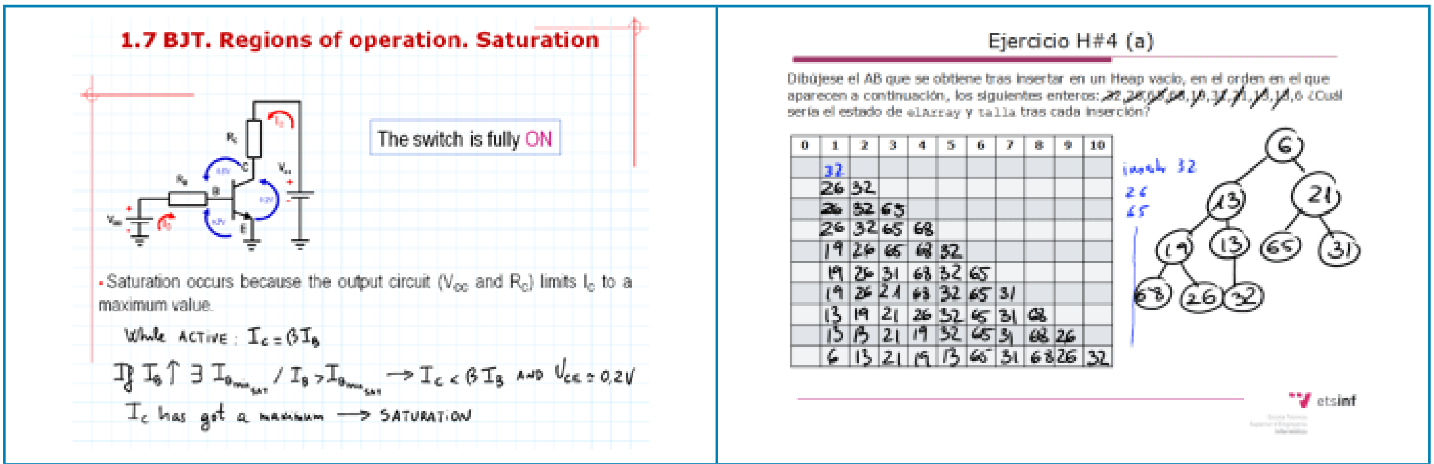


Figure 3: Sketch of the "Half-baked" pattern

a "Half-baked" pattern (see Table 3) that fits with the "Understanding" goal category referenced in Table 2 and it demonstrated the teacher ability to instantiate such pattern by completing its presentation with handwritten annotations. Figure 4b shows a similar application in the case of a "Filling blanks" pattern within a Data Structure subject. In this example, the instructor who implemented the pattern instantiation confirmed the way to design an interactive learning task that allowed him to check a data structure operation.



a) "Half-baked" implementation sample

b) "Filling blanks" implementation sample

Figure 4: Example of pattern deployment

5. Conclusions

The current work has described an approach to use patterns in the design of learning scenarios supported by technology-enhanced settings. The choice of design patterns was performed after the review of different mechanisms to represent learning issues in a formal or semiformal way. The proposed approach has taken advantage of the pattern features which combine the narrative textual-based expression power with visual notations easy to understand by non-computer literate users. These design patterns have been considered flexible enough to be adapted to different instructional conditions enabling the representation of multiple types of learning scenarios and they have been extended with new features such as tags that complement the pattern diagrammatic information and keywords which permit to identify fundamental concepts in the pattern description and connect them with instructional issues.

This pattern-based approach has been applied in an educational context corresponding to Computing curricula in order to validate such approach. In summary, a two-phase process has been performed i) to prepare a list of design patterns associated to a technology-enhanced setting based on digital ink technologies and ii) to deploy these patterns in this kind of settings demonstrating their effectiveness. The approach application has enabled the generation of digital-ink patterns which have been used by teachers in specific learning scenarios and the obtained outcomes have revealed a general pattern success among involved teachers. However, such experiences have also shown that some teachers are still reluctant to apply these representation mechanisms and their application requires a stronger practitioner support. Moreover, it must be acknowledged that evaluation experiences have been developed on isolated learning scenarios and other experiments are needed to generalize the pattern application in learning sequences and flows.

Other further works include, on the one hand, the preparation of new pattern catalogues, the development of wizard tools that assist instructors in the pattern application and the research in the integration with ontology notations. On the other hand, new cases studies are being planned to complete the approach evaluation, taking into account other issues such as the student performance or their point of view about the benefits of a pattern-based learning approach.

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Appendix A. Digital-ink pattern catalogue

Category	Name	Short description
Content manager	Light and shade	Some content items need to be clarified using an extra explanation or highlighted by means of visual artifacts.
	Focus of attention	There are items that require to be located, by signaling, underlining or framing certain information (e.g. Pointing out a diagram or underling a sentence).
	Half-baked	Some resources such as slide-based presentation can be completed on the fly by using freehand inputs to facilitate presentations or improve the discourse.
	Augmented reality	Some content resources such as images, video sequences or documents are better understood if additional information items are placed on them.
Activity facilitator	Make connections	There are activities that require to link or set up relationships among their component items.
	Do it freehand	Some activities entail the elaboration of a diagram, drawing a sketch or introducing an equation.
	Sharing efforts	Several students need to participate and collaborate to solve a problem, sharing and exchanging information.
	Organize your ideas	A learning activity can require elaborating a concept or mind map.
	Filling blanks	Different activities can demand to introduce information on a previously prepared structure (text, table, diagram, map…)
Interaction enabler	Raise your question	Anonymous contributions can help those students who are reluctant to ask in public (this pattern could be related with "Focus of attention").
	Post your opinion	Students can contribute with their point of view in a topic discussion.
	The audience responds	A poll mechanism can be used to gather the overall student preferences or the knowledge about a topic.
	Exchanging messages	Students should communicate among them during a collaborative task (this pattern could be related with "Sharing efforts").
Assessment producer	The right option	A rapid answer to a closed set of questions (objective test) is required.
	Connection game	A learning activity based on matching options could be evaluated (this pattern could be related with "Make connections").
	Grading opinion	The student point of view about a certain topic can be assessed (this pattern could be related with "Post your opinion").
	Bad news	Instructor can signal or remark the corrections made in the student works (fixing common mistakes).
	Good news	Instructor can highlight the strong points in the student works (providing positive reinforcement).

Appendix B. Instructional requirement questionnaire

Contents	Text documents require introducing special marks on them.	☐
	Images such as photos, graphics, or diagrams need annotations or additional descriptions.	☐
	Slide-based presentations require some kind of annotation or highlighting their components.	☐
	In video sequences or "screencast", some elements need to be signaled or marked.	☐
Activities	Students have to carry out matching or filling blanks exercises.	☐
	Course exercises require "freehand" inputs (e.g. symbols, equations, diagrams…).	☐
	Students are required to summarize topics by using a graphical representation.	☐
	Students share tasks in which annotations or diagrams are produced.	☐
Interaction	Students can anonymously ask questions focused on the course resources during the class sessions.	☐
	Students can post their point of view about a certain topic.	☐
	Students participate in collaborative works.	☐
	Students can vote or select a certain topic.	☐
Assessment	An objective assessment is performed using a closed set of answers or matching options.	☐
	Student opinions about a certain course topic can be assessed.	☐
	Instructors perform annotations on the works delivered by students.	☐
	Some student responses are selected and reviewed in front of class.	☐

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