From Pedagogical Paradigms to Hypermedia Design Patterns: Where to start?

Franca Garzotto
HOC - Hypermedia Open Center
Department of Electronics and Information
Politecnico di Milano, ITALY
garzotto@elet.polimi.it

Symeon Retalis
Department of Technology Education and Digital Systems
University of Piraeus, GREECE
retal@unipi.gr

Aimilia Tzanavari
Department of Computer Science
University of Cyprus, CYPRUS
aimilia@ucy.ac.cy

Ignazio Cantoni
HOC - Hypermedia Open Center
Department of Electronics and Information
Politecnico di Milano, ITALY
icantoni@como.polimi.it

Abstract: Several studies exist that have reached the conclusion that there are significant correlations between learning style and learning outcome. Therefore, it becomes apparent that since a successful instructor is one who achieves the best "learning outcome" from most of his/her students, then he/she should be able to cater for his/her students' different learning styles. When the instructor's role is played by an educational hypermedia system, then its capabilities should be such so as to deal with different learning styles – something that can be regarded as primarily a design issue. This paper introduces the idea of using design patterns to provide solutions to the problem of how to best support learning styles via educational hypermedia applications.

1. Introduction

In education, instructors adopt different instructional modes that correspond to their preferred teaching style: some focus on principles and others on applications; some present the material in a logical progression of small incremental steps, others proceed from the big picture to the details; some lecture and provide information using mainly spoken or written words, others like to present visual material, demos and experiments; some expect that students simply listen and watch, others provide frequent opportunities for discussing, questioning, and arguing. On the other side, students are characterized by different learning styles: preferences or predispositions to behave in a particular way when engaged in a learning process. Different students preferably focus on different types of information, tend to operate on the perceived information in different ways, and achieve understanding at different levels. For the purpose of this paper, we use the terms "learning style" and "learning preferences" interchangeably.

A number of studies in traditional class based education (Pask 1976; Felder & Silverman 1988; Claxton & Murrell 1987) show that students whose learning styles match with the instructional approach "tend to retain information longer, apply it more effectively, and have more effective post course attitudes towards the subject than do their counterparts who experience learning/teaching mismatch" (Felder et al. 2002). On the other hand, we know that

functioning effectively in any professional environment requires a lot of mental flexibility and the ability of working well in multiple learning modes. Consequently, the goals of a "good instructor" should be not only to adapt, at some degree and at least part of the time, his/her instructional approach according to students' learning preferences, but also to help students build their skills according to their favored and less favored learning preferences.

In e-learning, where the human instructor is replaced, totally or partially, by a computer application, different instructional approaches correspond to different application properties, e.g., different types of content, different organization structures for the educational material, different interactive activities in which students are engaged, different kinds of tutoring and scaffolding - in other words, different design solutions. Paraphrasing the claims in the above paragraph, we can say that a "student centered" e-learning application should aim at reducing the mismatch between the users' learning styles and the design solutions adopted by the application, but also, at some point during the e-learning experience, expose students to different instructional approaches.

We have investigated these issues in a specific category of e-learning systems, educational hypermedia (Brusilovsky 2001). With the term "educational hypermedia", we mean multimedia interactive systems that are mainly navigation-based and built for educational purposes.

Our research attempts to identify examples of "good matches" between learning styles and application design solutions. These examples can be used as design guidelines both for educational hypermedia designers, who can use them to build educational hypermedia that match a specific learning style.

We model these guidelines in terms of *design patterns*. According to the classical definition of architect Alexander, the pioneer of design patterns (who applied them to architecture and urbanistics), "… a design pattern describes a *problem* which occurs over and over again in our environment, and then describes the core of the *solution* to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice" (Alexander et al. 1977). In its simplest form, a design pattern is a recurrent problem associated to a design solution within a specific context. It provides a structure for integrating the analysis and solution of a problem, in a way that is sensitive to context and is informed by theory and evidence.

In our approach, the *problem* component of a design pattern is described by an *instructional goal* (e.g., a learning preference that the designer, or the application, needs to address); the *solution* component describes the desired *design properties* that the application should have, concerning its types of content, its organization structures, and interaction or navigation capabilities.

By its very nature, any design pattern is intrinsically heuristic, being founded on design practice. In our patterns, we try to capture the experience achieved in traditional educational frameworks and reported in the literature of pedagogy, cognitive science, and instructional design. These disciplines provide us both models for describing instructional approaches that work well (at least in some authors' opinion) for some specific learning preferences. Our patterns attempt to translate "traditional" instructional design solutions in terms of hypermedia design properties.

The rest of the paper is structured as it follows. Section 2 discusses the model we have adopted for representing learning styles, as well as the design dimensions along which we can describe hypermedia application properties. In section 3 we present some examples of design patterns for educational hypermedia and in section 4 we draw the conclusions.

2. Modeling Learning Styles and Hypermedia Design

"Learning style" is a broad concept which has many different meanings. In general terms, a learning style can be defined as a composite of characteristic cognitive, affective, and physiological factors that serve as relatively stable indicators of how a learner perceives, interacts with, and responds to a learning environment. Pedagogy and cognitive sciences provide a wide variety of learning styles models (Riding & Cheema 1991; Felder &Silverman 1988; Kolb 1984) that often differ more in name than nature. In the following, we introduce the Felder/Silverman learning style model (Felder & Silverman 1988), one of the most used in engineering education – the field we are

more familiar with. Still, our approach is largely independent from the chosen model, and the patterns we present refer to attributes that (although with different names) occur in most learning style models.

According to the Felder/Silverman model, a student learning style can be defined by a set of attributes, each one related to a different learning "dimension", as reported in (Tab. 1).

Learning style dimension:	**Question about…**	**Learning style attribute**	**Attribute definition**
Perception	How does the student tend to perceive the world?	*Sensory*	a sensory student perceives the world mainly by observing it and by gathering data through the senses; (s)he tends to be concrete, practical, oriented towards facts, procedures, and experimentation; (s)he is good in memorizing the above kinds of information; (s)he tends to solve problems by exploiting standard methods
		Intuitive	an intuitive student perceives the world mainly through intuition, i.e., indirect perception by way of the unconscious – speculation, imagination, hunches; (s)he can be innovative, good in grasping new concepts, creative, able of "inspired guesswork"
Input	Through which sensory channel does the student prefer to receive external information?	*Visual*	a visual student remembers best what (s)he perceives in a non strictly verbal form (e.g., pictures, diagrams, flow charts, symbols, videos)
		Auditory/Verbal	an auditory/verbal student remembers much of what (s)he hears and then says; (s)he likes auditory presentation (e.g., lecturing) or visual representation of auditory information (e.g., words, mathematical symbols, …)
Process/ Knowledge Building	How do students prefer to process information and convert it into knowledge?	*Active*	an active student learns best by doing something "physical" (i.e., something in the external world) with the information, e.g., experimentation
		Reflexive	an active student learns best applying some forms of reflective observations, examining information introspectively, focusing on the internal world of ideas, drawing analogies, and formulating personal views and interpretation of the information
Process/ Understanding	How does the student progress towards understanding?	*Sequential*	a sequential student prefers to proceed in a logically ordered progression, with each step following logically from the previous one; (s)he understands a complex issue through small, analytical, incremental steps; (s)he tends to follow logical stepwise paths in finding solutions and, even if (s)he does not fully understand the material can nevertheless do something with it (e.g., solve relatively simple problems)
		Global	a global student learns in "fits and starts", and must get "the big picture" before individual pieces fall into place (but at this point (s)he can put things together in novel ways) ; (s)he does better by jumping directly to more complex and difficult material than absorbing each detail of a subject

Table 1: Learning Styles Indicators (Felder/Silverman Model)

According to most hypermedia design models (Garzotto et al. 1995; Scwhabe & Rossi 1995; Isakowitz et al. 1995) the key features of a hypermedia application can be described in terms of four main design dimensions:

- the **content** (in the education domain, the educational material that the learner can explore in the application);
- the **navigation** and **interaction** capabilities by which (s)he can explore the content and interact with it;
- the **activities** in which the user can be engage and by which (s)he can modify the content and navigation structures (e.g., by marking some interesting material, by collecting material in personal "lessons") or the user representation (e.g., by answering some questions or tests);
- and the **lay-out**, i.e., the concrete presentation on the screen of all the previous features.

Following the presentation philosophy adopted for describing learning styles, we describe design dimensions in terms of designer's questions and we provide some examples of their possible answers, or "design attributes", as reported in (Tab. 2). Like a learning style is modeled as a combination of learning attributes, the design properties of a hypermedia application can be described as a combination of design attributes along the different dimensions.

Design dimensions	Question about…	Design properties	Examples of design property "attributes"
Concepts and Content	Which educational material should the application provide?	*Concept types*	Fact, phenomenon, example, theory, principle, demonstration, consequence, application, comment, etc.
		Relationship type	Precondition, assumption for, consequence of, example of, application of, exemplification of, details for, etc.
		Object structure	- Rich structure (composite objects, with clearly identifiable components) - Poor structure (simple objects)
		Media types	- Visual: image, video, animation, diagram, - Sound - Text
Interaction	Which interaction style?	*Interaction Style on active media*	- Active (full control) - Couch potato (passive)
Navigation	Which navigation style?	*Navigation topology*	Possible "navigation patterns" to explore collections of objects or interrelated objects (Isakowitz et al. 1995), e.g.: - Guided tour - Index - All-to-all - Hierarchy
Activity	Which operations and activities can the learner be engaged with?	*Operation/Activity Template*	- Mark topics of interest and collect them in a personal bag - Answer questions posed by the system - Fill in assessment questionnaires - Participate to collaborative activities
Lay-out	Which lay-out properties for contents and interaction elements? (e.g., navigation/operational buttons, etc.)?	*Composition style*	many/few content elements in the same page
		Colors	many/few colors
		Media formatting	Big /small size, etc.
		Interaction placeholders	- Textual - Iconic

Table 2: Design Properties/Dimensions

3. Mapping Learning Styles to Design: Patterns for Educational Hypermedia

The modeling framework outlined in the previous section allows us to represent a pattern for educational hypermedia in an abstract way, in terms of a many-to-many relationship from learning attributes to design properties (Fig. 1).

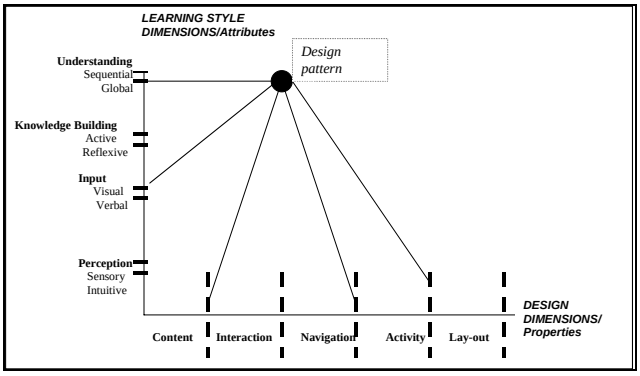

Figure 1: Conceptual Representation of Educational Hypermedia Patterns

Even though design patterns usually have a richer structure template (Garzotto et al. 1999; Rossi et al. 1999; Nanard et al. 1998), we adopt a simplified format based on two components: <problem, solution>. The solution component is structured in various sub-components discussing portions of a design solution along different design dimensions (content, navigation and interaction, activities, and lay-out). These are suggestions rather than prescriptions, and are intentionally incomplete: As for any design pattern, they offer guidance but require embellishment.

We include an example pattern, the "Global Learner" pattern (Fig. 2), which presents the design features that an educational hypermedia application may support to address the needs of a learner having a "global" learning preference. As shown by the example, the design solutions expressed by our pattern predicate about *types* of contents, organization *structures*, *media types*, navigation *topologies*, interaction *modes*, interface *templates*, and similar. Using a software engineering or a database terminology, we can say that these are schema properties that concern the "general shape" of the application, i.e. its "design in the large", rather than local, fine grained features, which instead concern with the so called "design in the small". Accordingly, we can say that our educational hypermedia patterns provide guidelines for design in the large, leaving the designers enough freedom when designing in the small, when they apply the design guidelines in the particular context and subject domain.

Pattern Name: Global Learner
Problem: address the needs of a **global** learner
Solution:

- *Content Issues*
  - Provide "the big picture" about a topic
  - Highlight (i.e., give emphasis to) advanced concepts
  - Provide information about and relationships to the "context" of a topic - theoretical/conceptual, or related to the everyday experience
  - Provide information about and relationships to relevant topics in different courses or disciplines
  - Include exercises at any level of detail about a topic
  - Include exercises that involve creativity and involve generating alternative solutions that differ from the "standard" ones
- *Navigation and Interaction Issues*
  - Provide the learner with a wide set of navigation facilities. Use indexes (possibly nested in hierarchies) more than guided tours (see "Index Hypermedia Pattern" (Isakowitz et al. 1995))
  - Support top-down learning, by allowing learners to start navigation from the "big picture" or the "overview" of a subject to the "steps" or the "details".
  - Allow learners to look for advanced concepts and to exercise even when all prerequisite elements are not yet fully explored
- *Activities Issues*
  - Allow the student to input alternative solutions beside offering the selection among a set of "standard" solutions
  - Allow student to input comments and criticism
- *Lay-out Issues*
  - In the different pages, highlight challenging exercises and challenging topics

Figure 2: The "Global Learner" Pattern

4. Conclusions

The core idea of our approach is the attempt to translate to the field of hypermedia based e-learning the main concepts expressed in traditional instructional design (Felder & Silverman 1988). Specifically, that each student has his/her own way of processing information, a factor that affects (along with native ability and prior preparation of course) how much the student learns – he/she gains most if the instructor's teaching style matches his/her learning style. However, if instructors teach exclusively in a certain style, then it is possible that students may not be prepared to function effectively in a professional environment, which normally requires a lot of mental flexibility and the ability of working well in multiple learning modes.

This paper attempted to show that in order to achieve similar goals in e-learning, we need to build systems that are designed with a focus on the learners' needs, in which the general properties of content, navigation, interaction, activities and lay-out features are set according to the user's learning preferences. We introduced the notion of design patterns which seems to be the key in achieving the economy of scale for building affordable software systems, supporting re-use in the form of analysis, design, or architectural components (which is even more important than simple code re-use).

The main goal of the paper was not only to argue that learning preferences and hypermedia design are related, but also to propose design patterns for e-learning that provide solutions to the problem of how to best support learning

preferences via educational hypermedia. Moreover, by presenting design patterns as strategies for educational hypermedia, we specify a new set of requirements for a new generation of such systems.

We are optimistic that design patterns are the proper conceptual tools. It is evident however that further investigation and a lot of R&D effort should be performed. The patterns presented here need to be tested and elaborated through empirical studies and system implementations. Further work needs to be undertaken to exploit the progress of learning technologies standards, which can aid in the description of the learning resources with meta-data and in the design and structuring of the learning resources content according to specific rules.

Within two European partnership projects, the E-LEN project [www.tisip.no/ELEN] and the ADAPT project [wwwis.win.tue.nl/~acristea/HTML/Minerva], special interest groups have been formed to share and develop design patterns regarding e-learning both for traditional hypermedia and for adaptive/ adaptable hypermedia, laying the foundations for a pattern language for such systems.

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