社団法人 電子情報通信学会
THE INSTITUTE OF ELECTRONICS,
INFORMATION AND COMMUNICATION ENGINEERS

信学技報
TECHNICAL REPORT OF IEICE

学習環境におけるヒューマンコンピュータ相互作用のためのデザインパタン
－コンセプトとプロトタイプ－

ブロイヤ ヘニング† 松本 充司‡

†‡早稲田大学 〒169-0051 東京都新宿区西早稲田 1-3-10, 29-7 号館
E-mail: †hbreuer@evangelion.ml.giti.waseda.ac.jp, ‡mmatsumoto@waseda.jp

あらまし 学習環境へのニューメディアテクノロジーとそれを利用する入出力インタフェースの統合は学習者サポートのための新しい可能性と必要条件を生み出す。このため本研究では、教室の学習環境、博物館または都市における学習環境のための新しい相互作用デザインパタン言語の作成を目的としている。我々は既存のソリューションを見直し、教室内外のマルチモード相互作用のパタンを提案する。我々は、ホワイトボード、ペンタブレットやPDA などの異なるフォーマットの連携を実現するソフトウェアのプロトタイプを開発・評価するとともに、ジェスチャーに基づく相互作用パタンを例示する。新たなパタン言語のレベルとそれに起因する特徴を述べた。

キーワード 相互作用デザインパタン, 教育工学, 学習理論, 行動理論, 教室, ホワイトボード, ジェスチャーに基づく相互作用

Interaction Design Patterns for Learning Environments
－Basic Concepts and a Prototype－

Henning BREUER† Mitsuji MATSUMOTO‡

†‡Graduate School of Global Information and Telecommunication Studies, Waseda University Waseda Bldg. 29-7, 1-3-10 Nishiwaseda, Shinjuku-ku, Tokyo, 169-0051 Japan 1-2-3 Yamada, Minato-ku, Tokyo, 105-0123 Japan
E-mail: †hbreuer@evangelion.ml.giti.waseda.ac.jp, ‡mmatsumoto@waseda.jp

Abstract The integration of new media and modalities into learning environments generates new potentials and requirements for learner support. Our research aims at creating an interaction design pattern language for formal and informal learning environments such as classrooms, museums, or cities. We review existing solutions and propose new patterns for multimodal interaction inside and outside the classroom. We explore, develop and evaluate software prototypes to support activities involving devices of different formats such as interactive whiteboards, pen tablets and PDAs, and present a gesture-based interaction pattern as an example. Levels and characteristics of an emerging pattern language are being described.

Keyword Interaction Design Patterns, Educational Technology, Learning Theories, Activity Theory, Classroom, Whiteboards, Gesture-based Interaction

1. Introduction

In the last 10 years a variety of new, computerized media has moved into the educational settings. Students carry mobile phones, PDAs and laptop computers into classrooms, which are equipped with interactive whiteboards and wireless network connections. During class or at home they retrieve and also contribute information online, always using different interfaces and functionalities. However most of the applications of these media have been developed for other purposes mostly related to business.

Oftentimes metaphors and interaction principles from personal computing have been transferred to these new devices and interfaces without taking into account the specific requirements of the new interface properties, or the potentials and the contexts of their use. An example for this is the use of desktop software like Microsoft Powerpoint™ for interactive whiteboards in the classroom. Pedagogic and situational limitations of this approach are hardly being discussed or even evaluated. Through literature review, observation, and interviews with teachers who use interactive whiteboards in their lectures, we have identified current limitations of standard software. We derive requirements for a software environment that ex-

ploits the potentials of interactive whiteboards in the face to face classroom setting, integrating various applications within a unique technical and visual framework. We proposed and evaluated a gesture-based interaction paradigm and a hierarchical semantic for a "DeepBoard" system [3]. The line of research presented here started from these results.

Even if, as in case of the "DeepBoard" a learner-centered software design approach has been followed for individual interfaces and devices, the learning environment they contribute to or compose is rarely designed in a reasonable way. Lacking comparable documentation as well as contexts and reasons for design decisions, the evaluation and improvement, and also the reuse of good solutions are rarely possible.

In our research, we synthesize two lines of development that have been dealt with independently so far: 1) the development and evaluation of educational technologies to support problem-oriented and collaborative learning activities inside and outside of the classroom, and 2) interaction design patterns as a means to document and generate design knowledge. Primary contributions consist in a basic layout of a pattern language for educational technology (starting with face-to-face learning environments), and a software prototype for enhancing classroom interaction through interactive whiteboards and multiple clients' access. First we will briefly introduce our approach to using interaction design patterns, then present the background on educational technology and learning theory, in order to bring the two together in a third step.

2. Interaction Design Patterns for Educational Technology

Interaction design patterns are standard solutions to recurring problems in interaction design. Originating from architecture theory they were adapted first to software development [6] and consequently to interaction design [2]. Pedagogical patterns have been proposed in order "to capture expert knowledge of the practice of teaching and learning in a portable, salient format." [12]. Usually they have been written and discussed independent of the technological development.

2.1. What are Interaction Design Patterns?

Interaction design patterns describe structural and behavioral features of a user interface, a Web site, an object-oriented program, or even a building. They are valid for the complete field of design they consider without determining a particular solution. Representing a framework for design they address and support interaction designers and developers in specifying interfaces. While some of them apply across applications, platforms and devices some devices like large or small screen interfaces require their own subsets of patterns. The goal is to improve, sometimes also to unify the user experience for interactive services and products.

Alexander [1] argued that architectural living patterns are generated by recurring events resulting from ordinary action of people. Patterns define a relationship between a context, a system of forces, which arises in that context repeatedly, and a configuration that allows these forces to resolve themselves in that context. In order to identify patterns one must observe and analyze their instances, and consequently abstract the properties that all good solutions have in common.

A system of relating patterns is called "pattern language". The term "language" stresses the rule-based order of components that provides coherence and may be used as a method for communication about design. The fact that individual patterns are integrated into pattern languages enables designers to use the collection for patterns generatively. Sub-patterns may be required to resolve more detailed design issues. A pattern language for a given subject usually presents its constitutive patterns in a hierarchical order with various links. We doubt there will be a well-defined body of pattern languages – its rigid structure may even inhibit innovation. Instead we trust in a discourse on patterns and their languages that will filter out insufficient solutions in the long run.

2.2. Which notation do we use?

A standardized notation would facilitate the exchange, discussion and evaluation of patterns, but no officially standardized notation for interaction design patterns exists so far.

However, the different notations being used are quite similar. Basically, „each pattern is a three-part rule, which expresses a relationship between a certain context, a problem, and a solution"[1]. Most authors also describe the conflicting forces within the problem domain and examples for the proposed solution as well as subordinate patterns. Sometimes there are only nominal differences between categories denominating the same or very similar constitutive aspects. In the context of our research we add, if available, information about empirical evidence to the example and related patterns even if they are not subordinate such as alternative patterns (OR), accompanying patterns (AND), and contrary patterns (NOT). Altogether

this results in the following notation:

(1) Name: A short, expressive and memorable name is introduced like a branding of each pattern.

(2) Context and superior patterns: Superior patterns and design space or the context of usage, i.e. a typical situation where the design problem occurs, is being described.

(3) Problem and forces: The design problem and its conflicting forces, e.g. technical and user requirements, are stated.

(4) Solution: The core of the patterns consists in a way to solve the design problem described before.

(5) Examples and evidence: Examples may contain sketches, prototypes or views into fully implemented systems. While they are only one out of many instantiations of the pattern their graphical form tends to be formative to the readers imagination. Therefore they should be well selected, remain rather abstract sketches or include some empirical evidence.

(6) Subordinate Patterns (include) and other related patterns (and, or, not): The recommended linkage between individual patterns helps to create a network of patterns (pattern language).

When it comes to pattern languages the challenge for a standardized notation and especially for a naming convention increases.

2.3. How do we use and generate patterns?

While classical works on HCI often focus on the critical evaluation in later stages of the design process, the discourse about patterns focuses on good solutions of recurring design problems. A distinguishing feature of our generative pattern approach is the combination of the critical and the generative potentials of patterns: to document and optimize existing patterns, but also to critically reflect upon them in order to generate new design knowledge.

Pattern languages may be developed bottom-up, top-down and in close interaction with users.

- Bottom-up: Abstracting and structuring results from user research such as field studies single patterns may be identified.
- Top-down: Reviewing existing solutions to structure an emerging pattern language framework.
- Interactive: Descriptions of patterns and their relation provide for an easily accessible way to discuss design alternatives and therefore establish a communication means for user participation in projects.

3. Concepts from learning theory

If we want to create and apply a pattern language for educational technologies inside and outside the classroom and make use of multimodal input and output channels some concepts from learning theory need to be taken into account, especially the notions of instructional media and of learner-centered design.

3.1. Instructional media and methods

Looking at learning environments from a psychological point of view we have to differentiate between the different codes, modalities and technical media being involved and view all of them in relation to the instructional methods they need to support [14]. While the instructional methods are ways to facilitate learning processes of the students, instructional media have been described as surface phenomena that solely deliver the methods [4]. The first interaction design patterns and implementations we have been working on focus on “presence learning systems” within the physical space of the classroom and take into consideration the following codes, modalities and technical media:

- In educational psychology coding refers to the symbol system in which information is being presented such as the verbal, pictorial or number system.
- While in psychology modality usually only refers to the sensory modality (vision, hearing, touch, taste, smell), in human-computer interaction modality also includes the input channels (sensors or devices) for the user. In the context our research we focus on keyboards and touch-sensitive input channels (pen-tablets and touch-screens on PDAs and interactive whiteboards) to create audio-visual output.
- Finally the technical medium refers to the carrier of media content such as a book, a video system, or a PC. In addition to these well-established technical media we look at interactive whiteboards, pen tablets and PDAs.

While there has been some controversy whether the instructional methods and structuring of learning content should be considered primary to media attributes, Jonassen et al. [8] proposed to proceed from an instructional-

and media-centered towards a learner-centered design instead. The latter approach focuses more on supporting than controlling learning processes.

3.2. Constructivism & learner-centered design

Quintana et al. [11] point out, that a learner-centered approach to designing interactive systems must differ from the user-centered perspective we have become accustomed to apply. Instead of forming a homogenous group of work professionals learner may often be very diverse. Within pedagogical psychology student diversity in the classroom has been capitalized within developmental contextualism [9], which looks at multilayered context within the classroom, and outside of school, such as home, peers, socioeconomic and cultural settings. Physical settings, social influences, personal characteristics and the influence of time are being considered as major forces of development. Similarly, cultural constructivism stresses the students' environment as a means to construct knowledge.

Constructivist approaches to teaching and learning propose open, but problem-oriented classroom activities [13]. Problem-oriented learning environments encourage self-directedness and collaboration as they combine explicit instruction (providing for guidance, orientation and help) and interest-driven constructive learner activities. Instead of presenting pre-fabricated learning content and transferring his knowledge into the students mind, the teacher acquires the role of a moderator for his students who co-construct their knowledge with his support, using various physical and cognitive tools and media.

The differentiation between instructional methods and media, codes and modalities, and the notion of learner-centeredness may provide us with some guidance in trying to line out a pattern language for learning environments. And how may we then suit the interaction to the theory?

4. Towards a pattern language for blended learning environments

The learner-centered approach suggests starting from student needs and activities in order to define system properties or interaction design patterns for educational technologies. With respect to instructional methods and their overarching influence on learning processes we expect patterns supporting them on higher levels than those addressing the properties of the media themselves. Trying to develop a framework for an emerging design pattern language for learning environments, we currently differentiate between five rough levels of potential learner support. For this differentiation we draw from works on activity theory [10], which emphasizes the cultural and technical mediation of human activity. Activity theory differentiates routine operations, goal-oriented, conscious actions and meaningful activities and understands learning activity as expansion in various forms [5], e.g. from a problem to a context to defining a new, advanced activity. Considering the potentials of defining patterns on levels of increasing generality, as well as the institutional embedding of many learning activities the categories we propose include an additional level for curricula and long-time learning goals, and one for organizational and didactical contexts, educational technology may hinder or support.

- Organization and didactics: Here we may also assume overarching design paradigms goal oriented consistency across platforms and devices, and the provision of support for different learner types, also organizational support impacting all levels of interaction. Different didactics refer to an instructional, constructivist or problem-oriented theory and practice of teaching and learning. (The open space environment offered by the DeepBoard Interface may be one of the patterns applying here.)
- Curricula and learning goals (or objectives) refer to time-bound bundles of courses and their contents. They include the instructional methods and are supposed to enable the achievement of learning goals that orient activities. Interaction Design Patterns on this level may include complete environments like learning management systems or interactive environments supporting instructional methods like small group collaboration, synchronous or asynchronous (presence or remote) communication.
- Activities in our understanding are derived from a subject or unit in the curriculum, or may be derived from the students' interests. Interaction design patterns on this level may provide a context for these activities and include group features like a shared screen mode for multi-device environments, multiple client access, a group awareness widget, but also educational games or virtual or blended learning environments.
- Tasks are necessary steps to fulfill an activity. Most individual and oftentimes de-

vice-specific procedures and applications supporting learning activities belong to this category. Examples may include modeling tools and simulators, achievement levels in games, specific training programs (e.g. vocabulary), or collaborative drawing and remote access applications.

- Operations: address the implicit reuse of previously gained knowledge. Interaction Design Patterns supporting operations include the gestures for gesture-based interaction, as well as most of the conventional interactive elements. Use of different codes, and support of different input and output modalities also belong here.

The definition of interaction design patterns should start with the activities, curricula and didactics they are supposed to support. Within the following table we try to match these hierarchical levels of didactics and student activities to technological properties.

Learner-centered	Technological
Didactics	Paradigms
Curricula	Systems
Activities	Environments
Actions	Applications
Operations	Functionalities

5. Interaction Design Patterns for Classroom Environments

We argue for and line out the minimum higher-level interaction design patterns that may turn interactive whiteboards into an open space for collaboration and support of problem-oriented learning activities in the classroom.

5.1. Preliminary high-level patterns

High level interaction patterns for learning environments address openness, collaboration, construction, and relation. With respect to the use of interactive whiteboards in the classroom we are currently working on the following ideas for patterns.

- Implementation of design patterns across platforms and devices within computer-integrated learning environments.
- Open space for constructive activities: provides a white-space to collaboratively create and edit content. Similar to the so called “open space technology” [7] as a method of group moderation, this open space is an answer to the question of how to deal with diversity: within an organization, a community, or even a classroom.
- Gesture-based interaction paradigm for touch sensitive devices (input modality): defines gestures to perform all necessary interactions directly on the whiteboard or from some tablet.
- Multiple client access: allows for multiple clients to access the whiteboard and to contribute content.
- Support of collaboration necessitated by tasks. Access orchestration allows granting and hindering access to the whiteboard. A group presence widget represents the student group and their position in the context of learning activities. A shared screen mode makes individual input accessible for all participants.

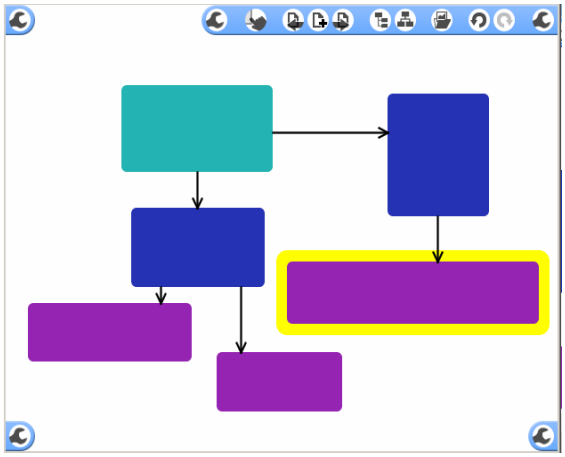
5.2. Pattern: Gesture-based input

To exemplify our approach we present a short version of the pattern for gesture-based input:

- Context: Problem-oriented or constructivist in-class learning activities, learning with whiteboards
- Problem: A central stage for projection helps to focus attention in class. Interactive whiteboards allow for flexible creation, editing and documentation of learning materials, but their use is often constrained by rigid software.

Spending too much time in activities, which are not directly related to teaching (typing long commands or queries, or searching for files) may interrupt the dynamic flow of the lecture and distract the attention of the audience.

- Solution: Provide for a gesture-based interaction that enables users to perform all activities related to teaching on the interactive whiteboard as the unique input and output device.
- Example:



(The image a screenshot of the whiteboard after the user has created and connected some node objects for creating or importing content. In order to do so he may apply simple gestures such as drawing an angle to create a node, drawing from one node to the other to connect them.)

- Subordinate patterns include the individual gestures, such as creating and linking nodes (as described in [3]), related patterns may include multiple clients' presentation, group presence widget, remote access, access orchestration.

6. Conclusion

We introduced an interaction pattern to the design of educational technologies and learning environments and proposed a preliminary framework for a pattern language. Currently we are implementing additional instantiations for some of the patterns we mentioned: the multiple client access for whiteboard interfaces with gesture based interaction and a shared screen mode for mobile devices supporting outdoor learning activities.

Our goal is to contribute to the development of a patterns language for formal and informal learning environments that seamlessly integrates architecture, interaction and software design. Instead of assuming persistent user characteristics we aim at developing tools and environments that unobtrusively support developing human beings, or learning users and organizations. In the process we try to adapt the notion of consistency as a primary design principle in HCI. Usually it has been related to properties of the software, instead of alignment with user goals, which incessantly change over time.

7. Acknowledgement

This research project is funded by NICT, the National Institute of Information and Communication Technology of Japan (http://www.nict.go.jp/index.html). We thank very much for this support.

Literature

[1] Alexander, C., Ishikawa, S. & Silverstein, M. (1977). A Pattern Language. Towns, Buildings, Construction. Oxford University Press: New York.

[2] Borchers, J. (2001). A pattern approach to interaction design. Chichester: John Wiley & Sons.

[3] Breuer, H. & Baloian, N. (2005). Augmenting Whiteboard Interaction in the Classroom. In: P. Kommers, G. Richards. (Eds.). Proceedings of ED-Media 2005. World Conference on Educational Multimedia, Hypermedia and Telecommunications. Association for the Advancement of Computing in Education (AACE), pp.1214-1221. Montreal, Canada.

[4] Clark, R. E. (1994). Media will never influence learning. Educational Technology Research and Development, 42 (2), 21-29.

[5] Engeström, Y. (1987). Learning by Expanding: An Activity - Theoretical Approach to Developmental Research. (http://communication.ucsd.edu/MCA/Paper/Engestrom/expanding/toc.htm)

[6] Gamma, E., Helm, R., Ralph Johnson, John Vlissides (1995). Design Patterns. Elements of Reusable Object-Oriented Software. Addison Wesley: Reading, Mass.

[7] Owen, H. (1997). Open Space Technology: A User's Guide. (2nd Edition). Berrett Koehler Publishers: San Francisco.

[8] Jonassen, D.H., Campbell, J.P., and Davidson, M.E. (1994). Learning with media: Restructuring the debate. In: Educational Technology Research and Development, (42) 2, 31-40.

[9] Lerner, R. M. (1991). Changing organism-context relations as the basic process of development: A developmental contextual perspective. Developmental Psychology, 27, 27-32.

[10] Nardi, B. A. (Ed.). (1996). Context and consciousness: Activity theory and human-computer interaction. Cambridge, Mass.: MIT Press.

[11] Quintana, C., Carra, A., Krajcik, J., & Soloway, E. (2001). Learner-centered design: Reflections and new directions. In J. M. Carroll (Ed.), Human-computer interaction in the new millennium (pp. 605-624). Massachusetts: Addison-Wesley.

[12] The Pedagogical Pattern Project. (2006). (http://www.pedagogicalpatterns.org/)

[13] Reinmann-Rothmeier, G., & Mandl, H. (2001). Unterrichten und Lernumgebungen gestalten (Teaching, and designing learning environments). In A. Krapp & B. Weidenmann (Ed.). Pädagogische Psychologie (S. 601-646). Weinheim: Beltz Psychologie Verlags Union.

[14] Weidenmann, B. (1997). Multicodierung und Multimodalität im Lernprozeß (Multicoding and multimodality in learning process). In L. I. Issing, & P. Klimsa, (Ed.). Information und Lernen mit Multimedia (S. 65-83). (2. Aufl.). Weinheim: Psychologie Verlags Union.