Enhancing Interaction Scenarios with a Domain-Oriented Pattern Language

Conference or Workshop Item

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ABSTRACT

We have developed a visual representation for enhancing interaction scenarios in the design domain of computer-mediated learning. We have applied the visualization within the Cognitive Apprenticeship model of learning. Each diagram is a visual abstraction for a learning activity design, complementing traditional storyboards and textual scenarios which are used by Instructional Designers. This has been valuable in focusing attention on high-level design properties and as a communication aid for collaborative design review. We describe how a series of abstraction levels in the diagrams leads toward a Pattern Language for important features of the design.

KEYWORDS

Interaction design, domain-oriented tools, visualization, scenario-based, learner-centered, pattern languages, education, learning environment.

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1. INTRODUCTION

We have developed a visual representation, called MCCA diagrams, for enhancing user interaction scenarios in the domain of designing computer-mediated learning (Carey, Harrigan, & Palmer, 1998). The diagrams are used by Instructional Designers in an early stage in the design process. Our representation is based on an existing model in Education called the Conversational Model (Laurillard, 1993). This representation has been used by novice and expert Instructional Designers who have found MCCA diagrams useful:

- to convey the different interaction which they could build into their designs
- to document instructional design decisions
- to act as a resource for team communication.

We have recently enhanced our representation by adding two levels of abstraction and we are beginning to use the three levels as a Pattern Language (Alexander, Ishikawa & Silverstein, 1977; Alexander, 1979) for user interaction scenarios. Initial feedback regarding our enhancements is encouraging.

In the next section we provide background information on the design scenarios, explain the Conversational Model, introduce Pattern Languages, and describe the domain of designing computer –mediated learning. In section three we detail our three levels of visual representation and show how they are being applied as a Pattern Language. We conclude with a discussion of some of our results, lessons learned, and a brief indication of our future work.

2. BACKGROUND

2.1 Design Scenarios

User interaction scenarios are recognized as a useful tool for requirements exploration and conceptual design for interactive systems. Scenarios are "narrative descriptions of what people do and experience as they try to make use of computer systems" (Carroll, 1995). They are concrete descriptions of work instances, but they can be informal and open-ended as appropriate in early design stages.

Despite the proven benefits of scenario-based design, scenarios are text-based and as such the scenario itself does not visually provide any information. MCCA diagrams complement scenarios by allowing the Instructional Designer to visualize key elements relating to the scenario.

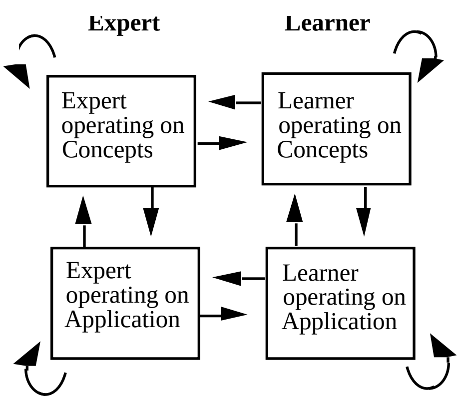

Figure 1. Laurillard's model.

2.2 Conversational Model

Our visual tool is an adaptation of Diana Laurillard's conversational model for mediated learning (Laurillard, 1993, p. 103) which was in turn is based on the work of Pask's Conversational Theory (Pask, 1976). We have adapted and applied the model for the design of mediated learning environments which are created within the Cognitive Apprenticeship model of learning. The Cognitive Apprenticeship model was first articulated by Collins, Brown, and Newman (1989). Its roots lie in the traditional methods by which apprentices acquire skill from experts, and its key features are modeling, coaching/mentoring, fading and reflection. Our adaptation may apply to other models of learning but to date we have focused exclusively on Cognitive Apprenticeship.

Figure 1 shows Laurillard's model graphically. We use her diagrams as a visual abstraction of a learning activity scenario. The representation highlights the role balance and relationships between expert and learner in the cognitive apprenticeship approach to computer-mediated learning, and the balance and order amongst the learning processes. The notation intentionally hides information about the content of the learning domain and the specific operations. For example, you would have to refer to the textual scenario to know why certain tasks took more time than others did.

Figure 1 categorizes user–system interactions into four classes, represented by the four boxes in the diagram. These reflect who is taking the initiative [expert or learner] and what kind of operations are employed [working with concepts or working on their application]. Using another learning model (such as Experiential Learning Cycle or Problem-Based Learning), of course, the categories of interest would be different. This categorization is oriented specifically for Cognitive Apprenticeship, but many of the design issues explored below have applications to other learning models. The four large boxes represent *operational* processes in computer-mediated learning, which involve operations on either an application problem or on representations of the concepts which need to be applied. In the cognitive apprenticeship approach, these processes could be performed by the learner or by an expert model. This leads to four types of operational processes:

Upper left process box: expert building concepts
Upper right process box: learner building concepts
Lower left process box: expert applying concepts
Lower right process box: learner applying concepts

Since the computer-mediated learning is intended to be highly interactive, *conversational* processes are also represented in the model. The arrow going from the upper left to the upper right boxes - from the Expert Operating on Concepts process to the Learner Operating on Concepts - represents an intervention by the expert, as mediated by the computer system, for a question or suggestion while the learner is engaged in building a concept. The arrow in the opposite direction is a request from the learner for the expert to model or comment on part of the concept building activity. The arrows leading back into their originating box represent reflective or meta-cognitive activities.

It is important to stress that the model represents two distinct, though strongly related activities, firstly the four operational processes described above, and secondly conversational processes which may take place while the operations are still being carried out. These two activities can occur independently and simultaneously, and a conversation may continue unbroken while there is a change of operational process, or vice versa. Thus conversations and operational processes are represented independently in the model.

2.3 Pattern Languages

A visual design representation for interaction scenarios is potentially a significant step towards a Pattern Language for user interaction scenarios, as explored in section 2.3. These visual forms, derived from the writings of the architect Christopher Alexander (Alexander, Ishikawa & Silverstein, 1977; Alexander, 1979) can capture design experience in a way that it is possible for others to reuse this experience.

In the design of software, patterns have been described as follows. "Design patterns capture the static and dynamic structure of solutions that occur repeatedly when producing applications in a particular context. Because they address fundamental challenges in software system development, design patterns are an important technique for improving the quality of software. Key challenges addressed by design patterns include communication of architectural knowledge among developers, accommodating a new design paradigm or architectural style, and avoiding development traps and pitfalls that are usually learned only by (painful) experience." (Coplien and Schmidt, 1995).

The HCI community, like many other fields of study, is at an early stage of attempting to determine the usefulness of Pattern Languages through exploratory workshops (Bayle et al, 1997) and some initial prototypes. In the next section, we examine aspects of the design process for computer mediated learning systems, as seen in design teams that we studied. This helps in understanding which aspects of the learning interaction it is useful to assist designers to visualize explicitly. Section 3 then looks at the various levels of representation we have developed.

2.4 Computer-Mediated Learning Interactions as a Design Domain

The success of a domain-oriented design environment depends upon the exploitation of opportunities for effective computer support uncovered within domain practice. The trick is to find niches within the … design process where valuable knowledge can be encoded in software… This requires a deep understanding of traditional practices and their bottlenecks … (Stahl, 1996).

Our work supports the design of computer-mediated learning environments. This is a domain where new design paradigms have emerged to support rich interactions for active learning (Harper and Hedberg, 1997; Fischer, Guzdial et al., 1995), but the new work models have not been widely disseminated in practice. We describe first a typical product of the design process, then consider the nature of typical design teams, their practices and the design bottlenecks which result.

Computer-mediated learning environments support the "work" of learning. That is to say, the work outcome is a change in the learners' knowledge of a particular subject domain. These systems reflect a variety of models of the learning process, including behaviorist drill-and-practice, structured subject presentations based on cognitive theories for comprehension, and more recently constructivist models of learning in which active manipulation of physical and conceptual objects enables learners to constructs their own understanding. The design teams with whom we worked were building learning environments to address subject matter which related a performance task to a conceptual or analytic base underlying the performance. The goal was for learners to build a base for future performance rather than just complete some set of performance tasks, an outcome which previous HCI research has shown requires particular care in interface design (Gilmore, 1995). The systems were intended to engage learners for one to three hours, targeting specific outcomes which could not easily be achieved without computer-mediated activities. The designers with whom we worked followed the principles of Learner-Centered Design (Fischer, Guzdial et al., 1995), an adaptation of user-centered design - although in many cases they were inexperienced with this approach. In the remainder of this section, we consider various important aspects of the design process under a number of headings.

Design process: The process included the following iterative activities:

- create profiles of target users, representing the major user characteristics
- specify target outcomes for each user
- build scenarios of existing learning, identifying work breakdowns [called "instructional bottlenecks"]
- design scenarios of new learning activities for each user, possibly including storyboards with design concept sketches
- create a "walkthrough prototype" and test with sample users
- build working prototype and test
- introduce into work situation and evaluate impacts.

Of course, this listing is artificially sequential.

There is little user involvement early in the process - this reflects the power dynamics of the context, and the limited system scope which focuses on one-time use. Consequently, the user profiles are essential in focusing the design on the target users and their characteristics, and previous research has demonstrated their impacts (Carey & Minstrell, 1996).

Table 1 contains an excerpt from an example user profile and usage scenario. The activity is from a system which engages the learner in the critical analysis of research papers in the professional field of Environmental Planning. The learners work with an expert resource person, presented through digitized video clips, as a partner in two activities: the analysis of a scientific article and creation of a one-page response paper on their reflections. Briefly, the users' tasks and their duration in the scenario are the following:

1 absorb cover story, describing a professional context and role [10 minutes]
2 review knowledge of applicable concepts through a self-test [15 minutes]
3 ask expert to describe concepts needing reinforcement [15 minutes]
4 observe expert analyzing related article [10 minutes]
5 analyze article to create notes for the response paper [20 minutes].

Design activity in context: The design teams typically include three roles:

- subject matter expert, in this case a faculty member in Environmental Planning
- expert in design of the work process, in this case an instructional designer
- interface designer responsible for prototype creation.

Table 1:Excerpts from a 2- Page Sample Learning Scenario for the *Critical Analysis* Learning Environment

Profile: Peter is a 21 year old full-time student... He prides himself in being interested in many areas outside his professional studies. He is an adept procrastinator and usually completes his work at the last possible moment. Peter is a holistic learner who focuses on finding the bigger picture…Peter will engage only briefly with his 'partner' to insure he is on the right track.

Scenario: Peter skims through the description of the professional role and context which situates the tasks…. From the description of the setting, he feels he is aware enough of the required process to complete the activities with minimal aid… Peter completes the self-assessment on categorizing assumptions and identifying key terms. He is surprised to note that his responses on two of the five items omit several points from the suggested answers. … Peter decides to engage with the expert partner to clarify when the additional points would be important… Peter remains unclear about some of the issues for finding underlying assumptions in the article he chose. He decides to invoke the expert to model this process on a related article, so that he can assess how much more effort to expend on clarifying his conceptual model… Now that he is satisfied that his grasp of the concepts will likely be sufficient, Peter returns to the target article and begins to select text indicating assumptions.

The subject matter experts were often operating with a non-interactive model of the learning process, without much exposure to computer-mediated learning as users themselves, and within their own work culture focused on performance over reflection [e.g., with little discussion of new work methods for learners]. The instructional designers were a scarce resource, so they were typically working on several design teams in which they provided periodic input but could not participate with the same focus as the interaction designers. The interface designers on the teams included both experienced professionals and novices. They had received some training in learning processes to compensate for the limited time of the instructional designers, but were also frequently engaging with user-centered design as a new process.

Challenges for design teams: Many of the design teams were challenged by the need to restructure the processes supported by the systems they were building. The existing processes suffered from the following breakdowns:

- poor integration between tasks. In particular, the existing systems encouraged an artificial separation between the tasks manipulating concepts and the tasks involving applying concepts. While the organizational goals stressed situated learning which integrated these two, in practice learners had been enculturated to focus on the application task since it produced the immediate deliverable
- poor role definition for the mediated partnership. In principle, the relationship between the user and the mediated expert was to be a cognitive apprenticeship (Collins, Brown & Newman, 1989), in which the expert modeled the construction of concepts and their application. The users, and many of the subject matter experts, had acquired expectations of the expert's role as 'laying out the rules' for the process rather than providing a model of what users would have to construct for themselves.

When the full team engaged with these issues, there were often communication difficulties as the subject matter experts and interface designers tried to coped with the new learning processes. Frequently the instructional design experts would be forced by time constraints to give cursory attention to the learning scenarios, especially for the differences amongst scenarios for different target learner profiles.

Usually the interface designers, who had the most time assigned to the team's work, were responsible for concretizing ideas resulting from design meetings. It was difficult for them to focus on the higher level issues of restructured processes, and design reviews often concentrated prematurely on surface aspects of storyboards and design sketches. This was a particular problem when the implementation technologies included trendy elements like interactive multimedia.

In principle, the textual scenarios could have provided the focus on process structure. In practice, they lacked the necessary structure to make the high level decisions explicit. The interface designers did not have a good model of the design space of high level options, and the instructional designers - who had such a model - were not able to quickly derive the process structure from the scenarios in the time they could make available. The concreteness of the scenarios, crucial to their success in focusing the design on users, detracted from communication on key issues like task integration and mediated roles. It was in order to address these problems and to make the necessary aspects of the interactions explicitly visible that we devised the visualizations for interaction scenarios presented in the following sections.

3. THREE LEVELS OF PATTERNS

We have created three levels of scenario visualizations which are: (a) the role balance and relationship between expert and learner, (b) a visual representation of the temporal nature of the conversational flow amongst the interaction actors, and (c) an overview of the types of work processes users engage in. Each of these levels is explained in the following subsections.

3.1 Level One: MCCA Diagrams

MCCA diagrams (Figure 2) highlight the role balance and relationships between expert and learner in the cognitive apprenticeship approach to computer-mediated learning, and the balance and order amongst the learning processes. The visualization is a visual abstraction of a learning activity scenario.

Figure 2 corresponds to the five tasks in the scenario described previously. The five points are summarized as:

1 absorb cover story [10 minutes]
2 review knowledge [15 minutes]
3 ask expert [15 minutes]
4 observe expert [10 minutes]
5 analyze article [20 minutes].

In the diagrams, each of the 25 grid squares within a quadrant represents one unit of time that the learner engages in that interaction – typically 5 minutes. The diagrams incorporate the temporal dimension by representing each task in the interaction by one column within a temporal grid in each activity box. The digits (1,2,3,4,5) in Figure 2 correspond to the five tasks within our sample scenario. Following these digits in sequence allows the designer to see the temporal nature of the interactions within the scenario. Note that the digits do not actually appear in the diagrams but are included here to make the temporal information more explicit. In general, everything in the four column 1's happens first, then everything in the four column 2's happens next, and so on.

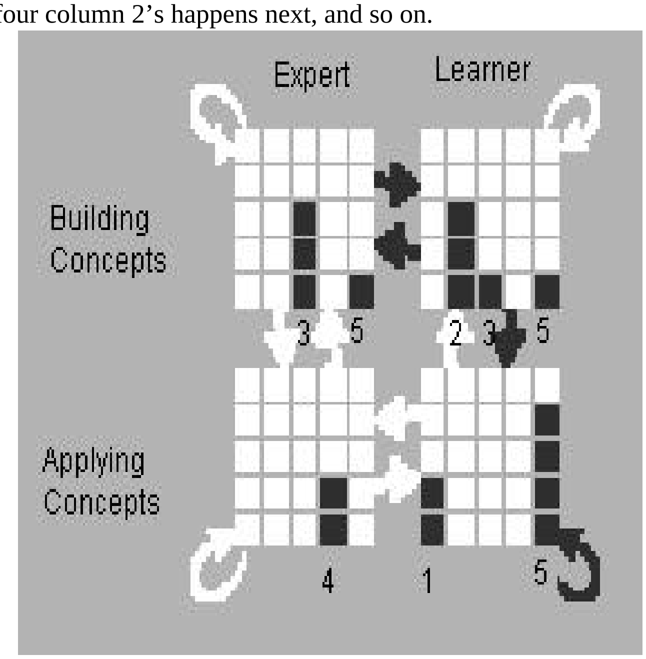

Figure 2. MCCA Diagrams.

The MCCA Diagrams are incorporated into a Design Kit (not shown) that allows designers to create a sequence of diagrams to represent a sequence of learning activity scenarios. This sequence of diagrams provides a gestalt view of the interactions in the sequence of scenarios.

The MCCA visual representation presented here is the fourth iteration of the representation. We have tested the versions with 16, 15, 7, and 10 subjects respectively. The results suggest ways these visualizations can aid in the design process:

- novices can employ the diagrams to incorporate cognitive apprenticeship principles in their designs
- experienced designers can use the abstraction to acquire a gestalt view of the learning conversations for discussion and critique.

We have used MCCA diagrams as patterns to illustrate the differences between various instructional theories. For example, one theory frequently employed to shape computer-mediated learning interactions is the Experiential Learning Cycle (Kolb, 1984), which sequences activities into four explicit stages: concrete experience, reflective observation, conceptual abstraction and active experimentation. Figure 3 illustrates the ELC theory. This diagram represents a design pattern rather than a particular design scenario. For example, some of the conversations are not filled in - because the extent of interaction with an expert is not specified as an element of the ELC pattern – though the pattern does require both operational and conversational processes. Also, there is no timing grid within the process boxes, because the pattern applies equally to a 20 minute learning activity and a 20 hour set of multiple learning activities.

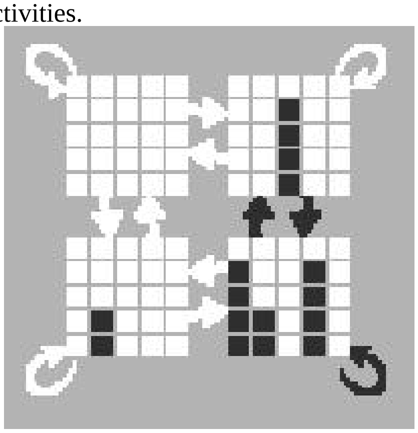

Figure 3. Experiential Learning Cycle pattern.

A related instructional pattern, Problem-Based Learning is represented by the MCCA diagram in Figure 4. Comparing the two patterns reveals the essential differences between them. For example, the PBL pattern relies extensively on the learner interpreting the needs of the application problem for direction in concept acquisition, whereas in ELC this can be mediated more by the expert (Barrows, 1986).

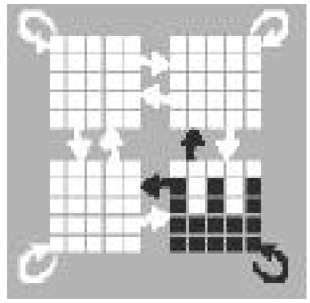

Figure 4. Problem-Based Learning pattern.

We found MCCA diagrams effective for representing these patterns of interaction scenarios and we are now investigating the extent to which the MCCA visual representation could be developed into a domain-oriented Pattern Language. The CHI97 workshop on Pattern Languages for HCI (Bayle et. Al, 1998) sets out some of the general issues which an HCI pattern language would have to address. Within our design domain, two developments seem to offer the most promise in this direction:

- Extending the structure of MCCA diagrams to work at multiple levels. This is described in the next two subsections.
- Extend the representation to better bridge between the artifact space the social world, by incorporating representations for collaborative learning activities.

3.2 Level Two: LIDs

LIDs are a variant of MCCA diagrams which explicitly show timing information for both operational processes and conversations. Figure 5 (on the final page of this paper) shows a sample LID. Just as in an MCCA diagram, divided blocks, or, in certain views, other solid geometrical shapes (figure 6) are used to show the duration of activities/processes (figure 5). The vertical arrows represent questions and replies. The temporal ordering of conversational interactions is represented by the left-to-right order of the arrows. The precise placement of events on the left-to right axis reflects onset times for activities and conversational moves. In a more detailed view than figure 5 (not shown), grid marks are added to the four horizontal lines (which represent the four modes of activity) to enable precise times to be read off more easily. LIDs can also show the duration of conversational moves, in addition to their onset times, as shown in figure 5. The number of 'beads' threaded on an arrow represent the duration of the corresponding conversational move in a suitable unit of measurement. Each bead represents, by default, 10 seconds of conversation, though this can be adjusted. In highly detailed views a LID (not shown), a bar of continuously varying length is placed on the shaft of each arrow, in place of the beads, to allow finer comparisons of duration. Note that the beads are horizontally aligned, even in the case of the reflective conversation (the arrow which loops back on itself), to help make precise visual comparison of durations easier.

LID diagrams appear to have good scaling properties: that is to say, essentially the same formalism appears good both for giving fine-grained accounts of interaction scenarios (as considered above), and for coarse-grained overviews (as outlined below), which are useful in pattern work, and for communicating gestaults to designers and analysts. Such scaling is an important and desirable property of visualizations (Brayshaw and Eisenstadt, 1991). One possible limitation of LIDs compared with MCCAs is that the two symmetries (left-right and top-bottom) between user vs expert, and concept vs application, which is readily apparent in both Laurillard's diagrams and in MCCAs, is less neatly apparent in LIDs. However, by differentiating the expert and learner part of the diagram in the LID (by shading the expert part, as in Figure 5), both of these symmetries can be communicated to the user, albeit in a new way.

Figure 6 shows a LID giving a coarse-grained view, or overview, of another educational interaction. This scale of view is particularly useful for the identification and study of candidate large-scale patterns in user interaction scenarios. Such overviews present what may be seen as graphs of the change over time of the balance of learning activities. In figure 6, the pattern involves an initial focus by the learner on work involving practical application. This applied emphasis is seen to tail off, until by the middle of the session, the learner is focusing almost exclusively on theoretical concepts, presumably abstracted from, or exemplified by, the earlier applied work. The emphasis then moves back to applied work, presumably applying the concepts just studied, until by the end of the session, the learner's activity is seen again to be almost entirely focused on application. In this candidate pattern, the learner works alone, with no significant involvement by the expert. We hypothesize that there are various such high-level patterns of computer-mediated learning to be identified, each with its own set of trade-offs and consequences, and each with particular relevance to identifiable types of subject area, particular kinds of student, and to particular teaching styles. We believe that the identification and description of such patterns will be a useful resource in the development and communication of design skills in computer-mediated learning. Long term aims of our empirical work include the development of a pattern language for user interaction scenarios based on the elements outlined above, and the testing of our hypothesis.

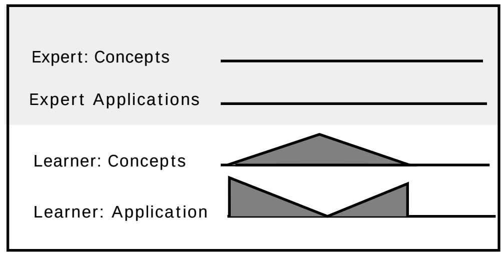

Figure 6. A course-grained LID

3.3 Level Three: Overview Diagram

One key design issue is the overall balance amongst the processes during the learner's interactions with the system. Figure 7 shows the highest level of our diagram that we have user tested, which is a summary of 80 minutes of user interaction. The size of shading in each box reflects the amount of time spent in each category of activity. We have found that experienced designers can use this representation to obtain a gestalt view of the instructional strategies employed – in this case, most of the learner's time has been spent building and applying the concept space, with relatively little initiative for the expert to present concepts or demonstrate their use. Figure 7 is an overview and does not show (unlike figure 6) such things as whether the expert's involvement came at the beginning to introduce the learning activity, at a specific point in response to a learner need, or at the end of the session as a summary or commentary.

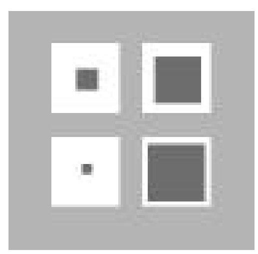
Figure 7. Overview Diagram.

3.4. Learnability Study

Design patterns appear to offer advantages for providing a gestalt view or abstraction to supplement scenario-based design. We have conducted learnability tests (10 subjects) with subjective feedback, and are now initiating usability and utility tests in a quasi-experimental setting. Our learnability results show that patterns can be illustrated at multiple levels of detail, (1) from an overview of the types of work processes users engage in, (2) through the role balance and relationship between expert and learner (i.e. MCCA Diagrams), (3) to a visual representation of the temporal nature of the conversational flow amongst the interaction actors (LIDs). In response to the statement "I found the diagrams straightforward and easy to use." the subjects provided average scores of 6.4, 5.7, and 5.9 respectively on a Likart scale of 1-7 where a 1 meant they were difficult to understand and a 7 meant they were easy to understand.

4. CONCLUSIONS

The visualizations appear to be useful for both novice and experienced designers. We have incorporated the diagrams into a design toolkit and we use this kit in a university design course. We will soon be using the kit in an actual work setting in cooperation with our corporate partner. This will allow us to do a more detailed analyses of the potential for using the visualization as a pattern language.

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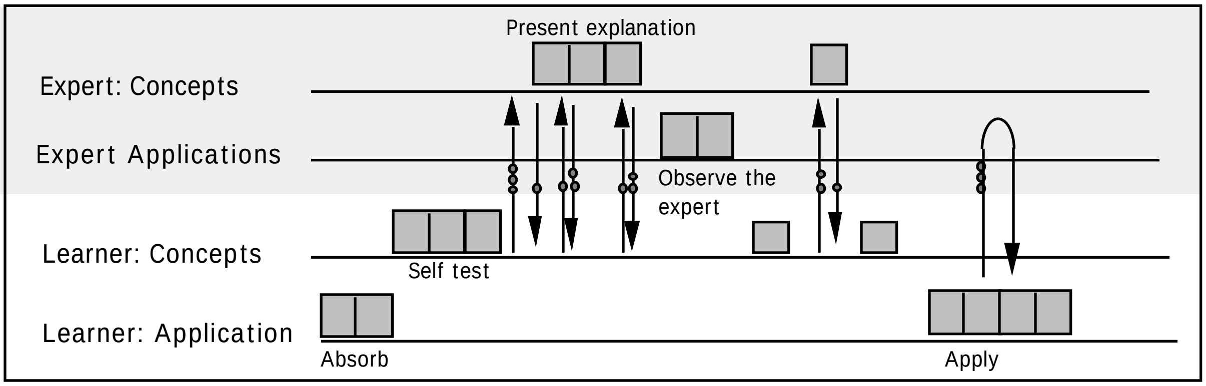

Figure 5: A LID showing the length of conversational moves using beads.