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Computer Science

Research Report

The Roles of the Computer in the Learning Community

Colin Harrison & James Penny

IBM Institute for Advanced Learning, Switzerland & UK
ch@zurich.ibm.com, pennjms@uk.ibm.com

IBM Research
Zurich Research Laboratory
8803 Rüschlikon
Switzerland

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IBM Institute for Advanced Learning, Switzerland & UK
ch@zurich.ibm.com, pennjms@uk.ibm.com
http://www.research.ibm.com/people/c/colinh

Abstract

We model the learning process as a set of semi-structured interactions between an instructor and a group of learners, among the learners, and between the learners and a body of knowledge. We propose to introduce the computer into the learning process as a mediator in time and space of such interactions. We will provide templates for such interactions in the form of directed graphs whose nodes contain learning experiences. Different learners will traverse these graphs in different ways according to their needs, roles, and abilities. We believe that this technique of modelling computer-mediated interactions will become a generalized technique, applicable in many areas. We will also model the conceptual space of the material being learned and provide a visualization of this space which will form a visual mnemonic for the learner. These models are based on learning object technologies for which open industry standards are now emerging and to which we will propose new extensions.

Learning – at its best – is the magical process of joining two minds together. As human beings we are genetically engineered to be learning machines in our infancy and perhaps we are also endowed with a gene for teaching. The face-to-face experiences we have with effective teachers are among the most formative moments of our young lives. The facility of an effective teacher to exploit the high-bandwidth, low-latency, multiple-modality communications channel is surely one of our most highly evolved skills.

It is a bi-directional process. The student receives information from the instructor, but the instructor also needs feedback from the student in order to assess whether the student understands. Effective teachers react to these cues and present alternative perspectives on the topic until all or as many as possible of the class members have "got it". Moreover this is a multi-modal process– the teacher speaks about the topic and supports this with visual materials, but also exploits the many non-verbal cues that humans typically employ. Likewise the feedback from the students depends on questions, but also on visible attentiveness and facial expressions communicating understanding or puzzlement. Learning and teaching are ultimately about the facilitation of people to move beyond what we know and to make new connections that can lead to the discovery of new facts. These new connections lead to understandings, insights and ultimately new knowledge. So Learning and Teaching are more than telling and remembering.

If humans are so well adapted to communicating and teaching, why do we want to introduce a computer into the process? We are driven to employ technology-based learning or eLearning by several forces: scalability, cost, the need to quickly teach new skills to a distributed workforce, the need to improve the overall effectiveness of education and training. But we are also drawn to employ the computer by a number of advantages it can potentially offer as a platform for communication, for storage, for calculation, and for visualization: the elimination of time and place as constraints on how learning is performed and the ability to expand the scope of learning beyond the limitations of the teacher's own knowledge and the resources of the educational institution. Ideally we also hope that eLearning will improve learning outcomes in unfavourable situations – less effective instructors or disaffected social environments. In the 21C we will also see the blurring of structured learning with the lifelong need to acquire and comprehend specific information to perform a new or unfamiliar task.

So our concerns in introducing a computer into the learning process are to center its use on the student, to give it a specific role as a member of the learning community, and to make the delivery of learning experiences as closely tailored to the needs of the individual student as possible. Our model for the interaction between the computer and the student is that the computer should be able to emulate some of the empathetic behaviour of the teacher in sensing the student's progress and adapting the scope or the perspective of the learning experience to the student's needs. Moreover we want to exploit the capability of the computer for worldwide, real-time or asynchronous interaction to expand the student's ability to find relevant information, to get a second opinion on questions, to engage in collaborative problem solving, and so forth. These activities are 21C skills that should be acquired by all students.

Previous work by Schnitz, Penny, and Azbell (2001) indicates that introducing digital media into classroom teaching significantly extends the range of instructional modes employed by the teachers and enhances the ability of students to engage in self-guided or team-guided learning experiences:

Technology Impact Matrix

Instructional Mode:	**Presentation**	**Mediated Presentation**	**Discovery and Construction**
Content Format:	**Fixed**	**Mediated**	**Manipulable**
Content Access Mode: **Linear**	Books Films/Videos Journals	*"Interrupted" Methods* *(e.g. DRTA)* *Worksheets*	N/A
Categorical	Lists Print Reference Works	*Guided Research*	**Data Files**
Random	Microfiche *Slides* **CD ROM Storage**	*Study Guides* *"Interrupted" Methods* *Annotated Files* **Algorithmically-structured content**	Leggos Math Manipulatives **Multimedia Files** ***Web Pages**
Shared	Broadcast	***Web-casts**	***e-Mail** ***Set-top box/web access** ***Web-page creation**
Collaborative	N/A	N/A	***Chat Rooms** ***Threaded Discussions** ***Synchronous White Board** ***Streaming Media**

NB: Plain text indicates analog content, **bold indicates digital,** and *italics* indicates content that can be either. *Text with an asterisk indicates networked (Internet)-based digital content.

Figure 1: Relationships between types of learning media and instructional modes (from Schnitz, Penny, and Azbell (2001)).

Suppose we model the student-computer interaction as a communication channel linking two Finite-State Machines (FSM). (We are not arguing that this is how learning takes place, but it will serve to illustrate the deficiency in the current Web model.) The user has a model – the FSM - of how he or she expects to interact with the computer and the computer has a model – its FSM – of how it is driven by and responds to the user. If these models are identical or very similar, then they will remain synchronized throughout the interaction and the user will find it easy to fulfill his or her expectations. If however the models differ, then before long the user and computer will have different beliefs – represented by the states of their FSMs – about the state of the interaction. For example, the user may seek to perform a certain action, and the computer's FSM may not permit that transition. We have all experienced the frustration of not being able to discover how to perform what appears to us to be the next step in an interaction with a program or a Web site, because it has a different model of what happens next.

A frustrated user is unlikely to have an effective learning experience. So we start by seeking ways to adapt the computer's task model towards the student's expectation. We intend to create a software entity that can express, that can react, that can change perspective and modality, that can question and sense understanding for the individual student. In effect the computer must have a model of how this student is most able to learn certain kinds of material, of the student's current mental state – engaged, confused, ahead of or behind the learning experience, and so forth, and even of the student's environment – indoors, outdoors, seated, traveling, the client device, the type of network connection, and so forth. Some of this information can be inferred from patterns of behaviour, some of elicited from the student, and some of it contributed by the teacher.

In the most satisfying and engaging interactions with a program or a Web site, the user ultimately senses that he or she is connecting – distantly and asynchronously – with another human mind. In our experience this is a rare event, but most commonly found in the absorbing interaction with certain computer or video games and in chatrooms or e-mail.

Having created a model for the student, we now need a mechanism to adapt the learning experience to that individual. The HCI community has recognized many years ago the necessity separating content and form, we now need to separate presentation from the control of flow of the presentation. That is, the hyperlink graph is continually re-computed as the student masters or fails to master each experience. We are greatly encouraged in this direction by the observation that mainstream Computer Science research directed at representing Next Generation Web experiences is converging with our goal of being able to develop interactive and adaptive rich-media experiences.

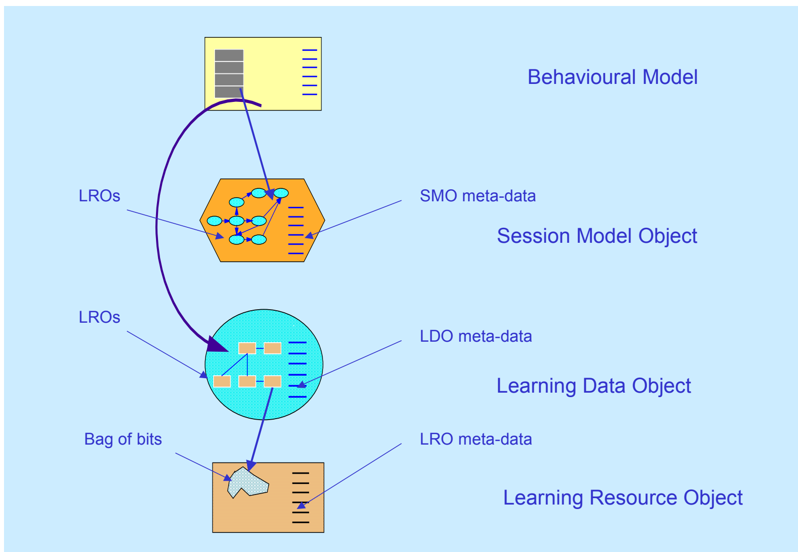

Figure 2: XML technologies are allowing us to construct adaptive, interactive, rich-media learning experiences by dynamically assembling learning content packaged to IMS or SCORM standards (Farrell & Jett (2002)).

Our colleagues Farrell and Jett (2002) are defining a sequencing language for standards-based learning objects that can exploit XML technologies such as Web Services Flow Language (Leymann (2001)) and Web Services Experience Language (Diaz (2001)). A related, but separate activity is the development of patterns for the effective presentation of different types of material (Wu and Ma (2001).

Our foundation for these adaptive experiences is the IBM 4-Layer Learning Model, illustrated in Figure 3. This model provides a range of experiences which include Learning from Information through presenting the content of the topic (layer 1), Learning through Interaction with the content by (guided) exploration of the structure of the topic, by simulation, and games (layer 2), Learning from Collaboration by discussion, by collaborative problem solving and practicing with us (layer 3), and Learning from Co-Location by face-to-face experience of the topic (layer 4). Students with different types of intelligences have different levels of engagements with these approaches and our research will explore how to apply these different teaching models to a range of learning models.

Figure 3: The IBM 4-Tier Learning Model is an example of blended learning, which combines technology-based learning with teacher and peer interactions and self-guided exploration.

So the computer has advanced here from the single role of "putting textbook pages of the screen" to several roles: presenter, modeler or game player, facilitator of collaboration, and it eventually steps aside when face to face interaction is available. It becomes a role player in the social activity of learning: communicating with the learner, observing his or her interactions with peers, and sharing insights with the teacher. It is not intrusive, but a team player, supporting the overall teaching process of joining two minds together.

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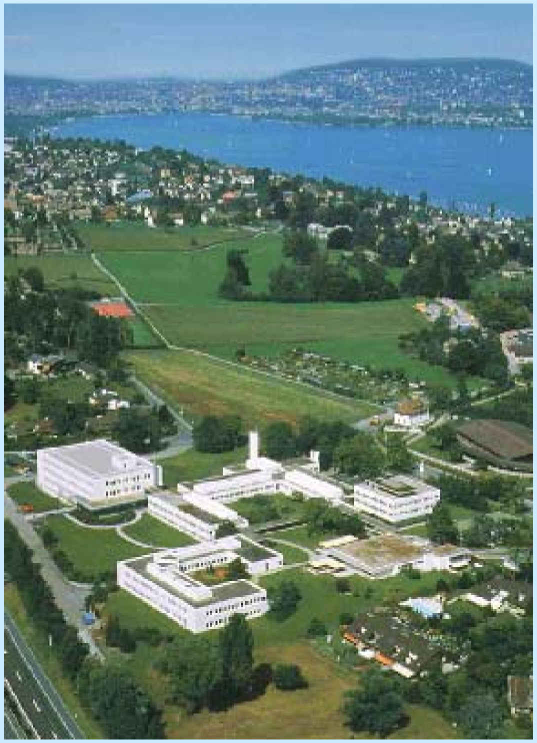
The Roles of the Computer in the Learning Community




Colin Harrison & James Penny
ch@zurich.ibm.com
IBM Institute for Advanced Learning
IBM Zurich Research Laboratory

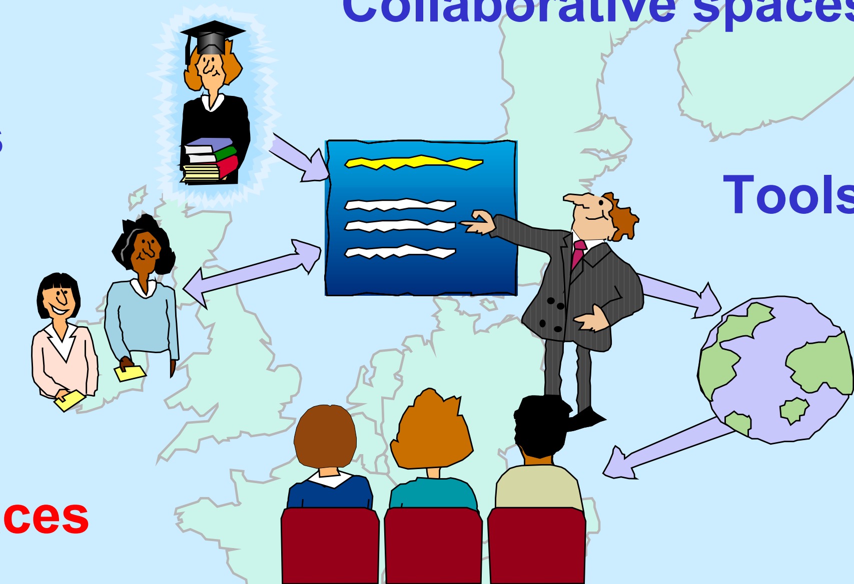
Building Effective Learning Environments…

What are the elements of computer based learning environments?

Collaborative spaces

Flexible tools

Tools that assist teachers



Interactive spaces

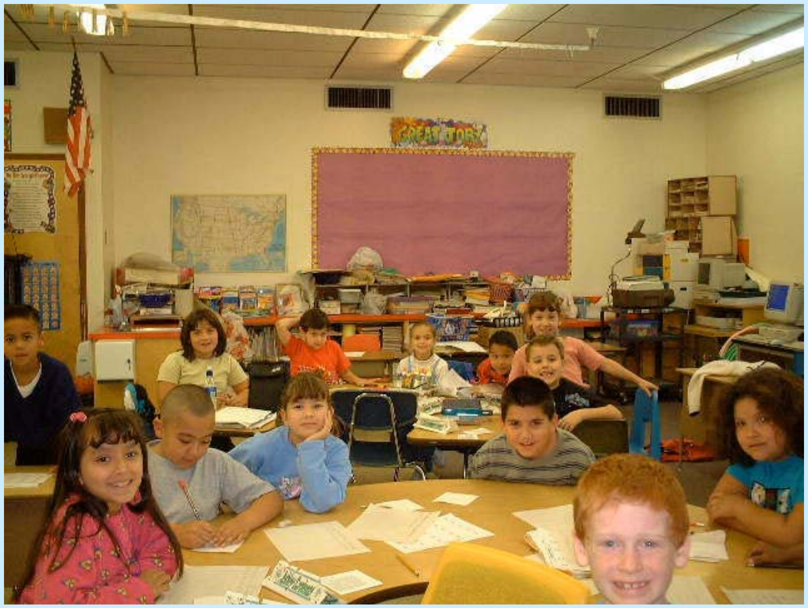
Enable users to shape and develop information space

For specified learning outcomes there is a need to consciously design an information space.

The Computer in the Learning Environment

- Roles for the computer in Learning
- Computer as mediator in human interactions
- Computer as vehicle for exploration
- Generalization and convergence

What goes on in here?



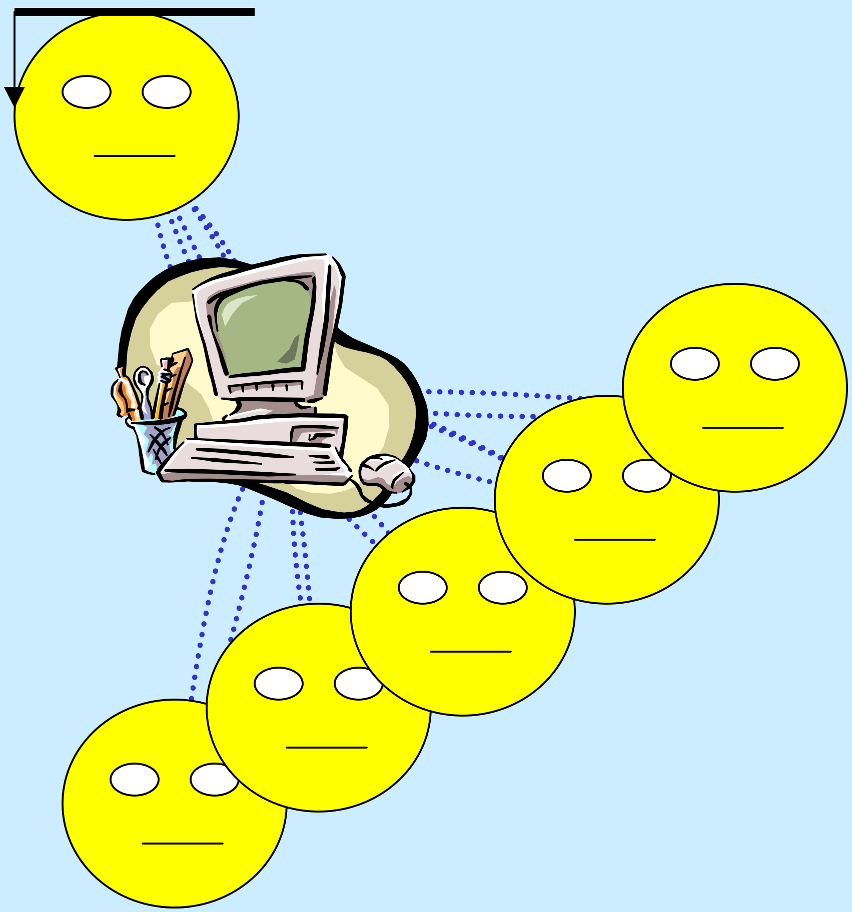
- The magic of connecting minds
- Complexity of a core human activity
- Basic learning is always mediated by a teacher
- How can adding a computer improve this?

How can adding a computer improve learning?

- Something to do with dialogues
- Something to do with access to information
- Something to do with enabling communication among a group of people who cannot be at the same place at the same time
- Something to do with interaction with simulations & games
- Something to do with individual learning
- Something to do with new methods of learning & assessment

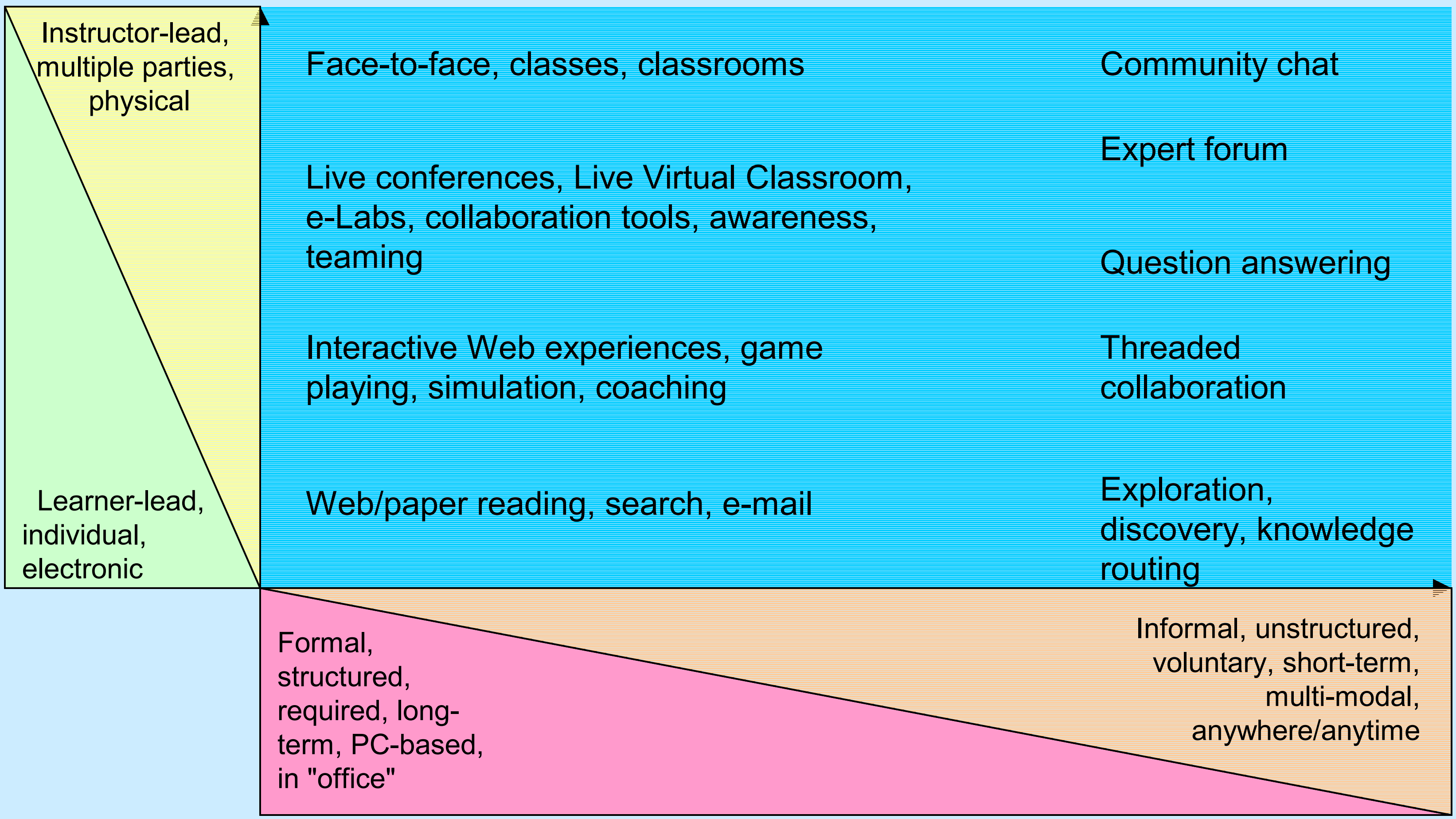
- What problem are you trying to solve?
  - Beyond my scope

Finding roles for computers



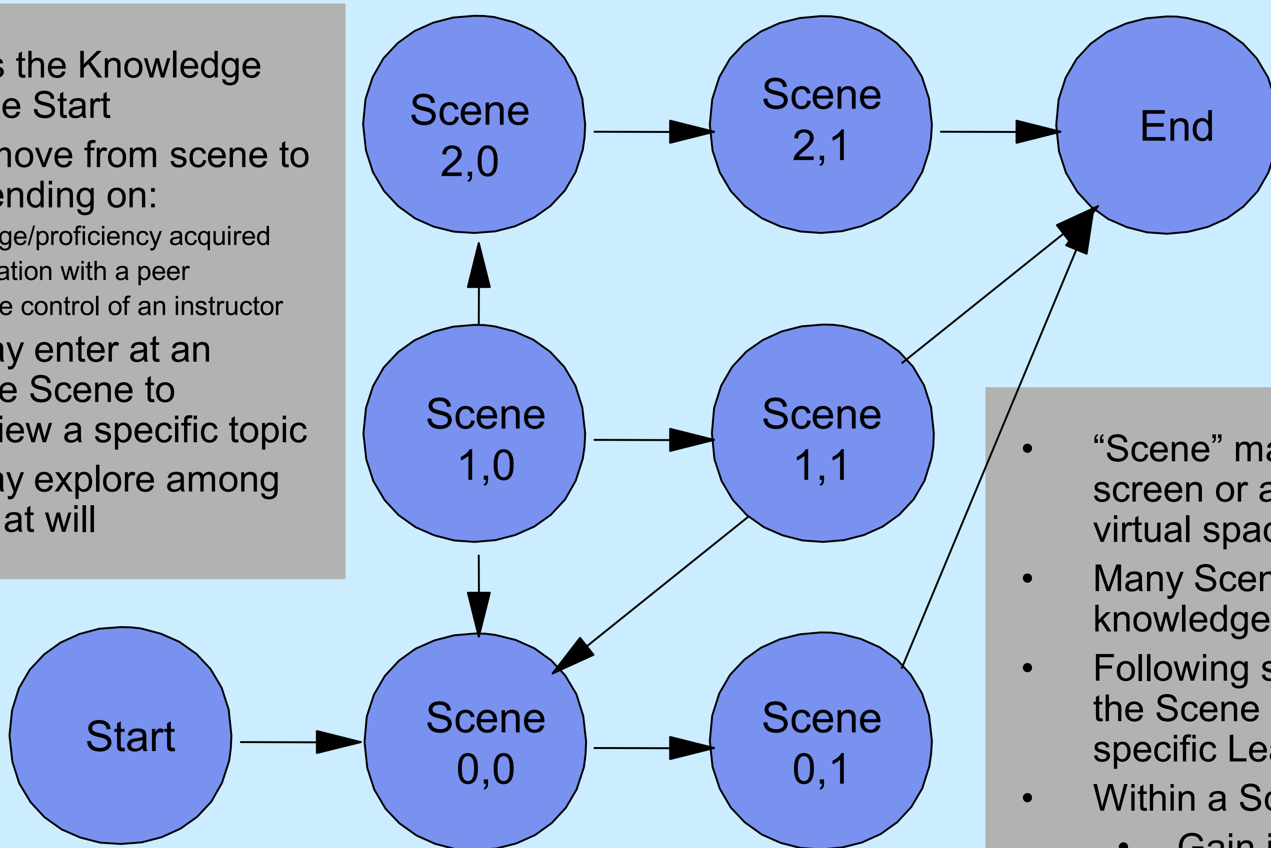
- How far can I get without trying to implement psychology?
- Observably learning is based on human interactions
- Can the computer be an effective mediator for these interactions?
- Mediating the interactions through the computer changes them – for better and worse
- Which computer-mediated interactions are effective in various forms of learning?
- How I know which interactions to use in specific instances?

Dimensions of e-Learning



Example of Navigation in Learning Space (1)

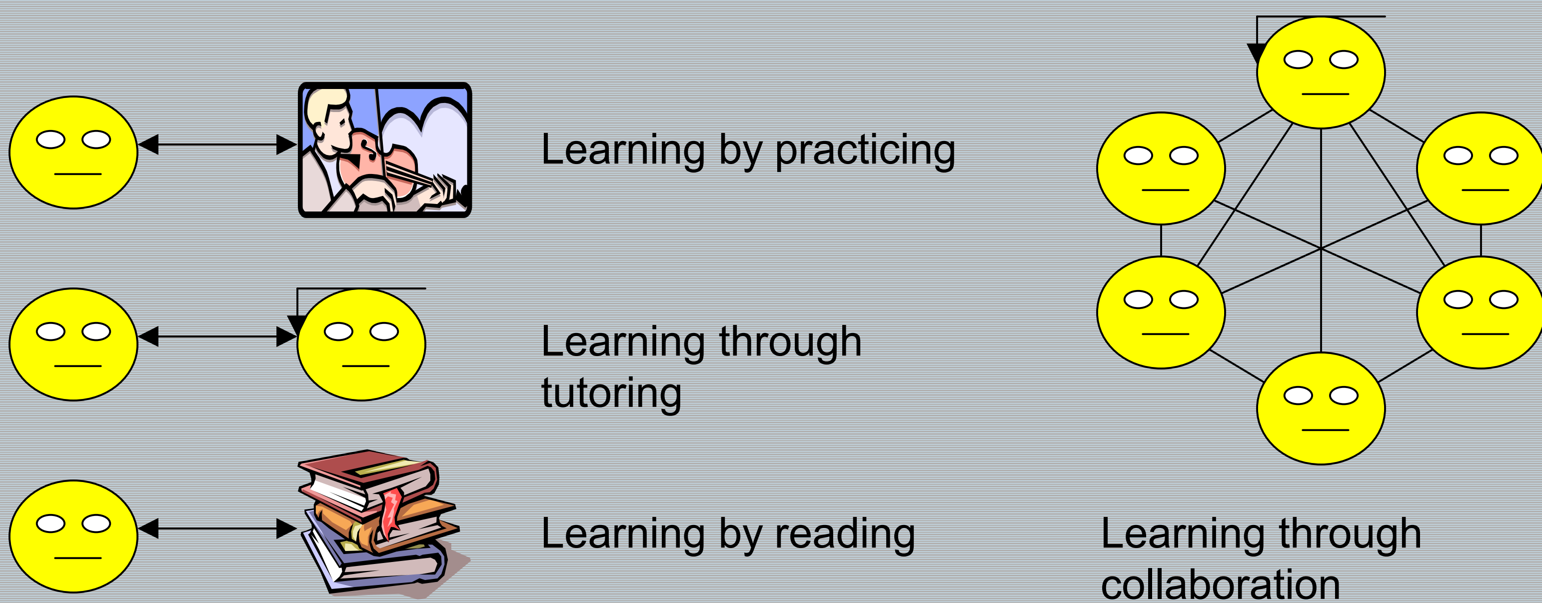
- User enters the Knowledge Space at the Start
- User may move from scene to scene depending on:
  - Knowledge/proficiency acquired
  - Collaboration with a peer
  - Under the control of an instructor
- Or User may enter at an intermediate Scene to acquire/review a specific topic
- Or User may explore among the scenes at will



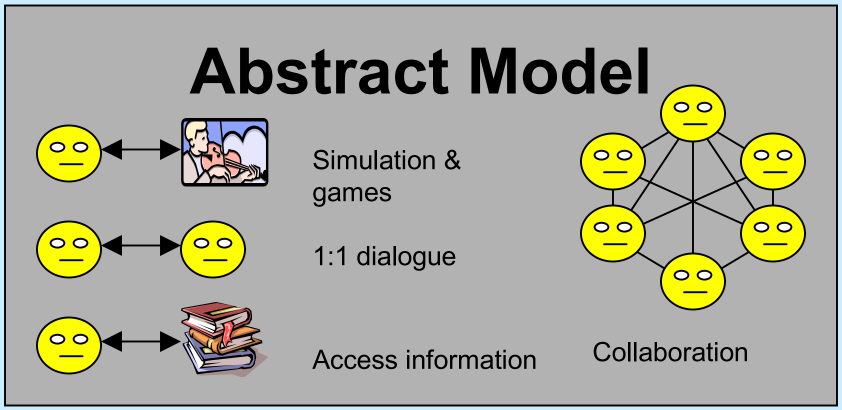
- “Scene” may be simple Web screen or a more elaborate virtual space like a game
- Many Scenes may exist within a knowledge space
- Following specific paths among the Scene is intended to achieve specific Learning Outcomes
- Within a Scene, the User can:
  - Gain information
  - Practice a new skill
  - Interact with other learners or an instructor or tutor
  - Validate learning with a test

Learning as Dialogues

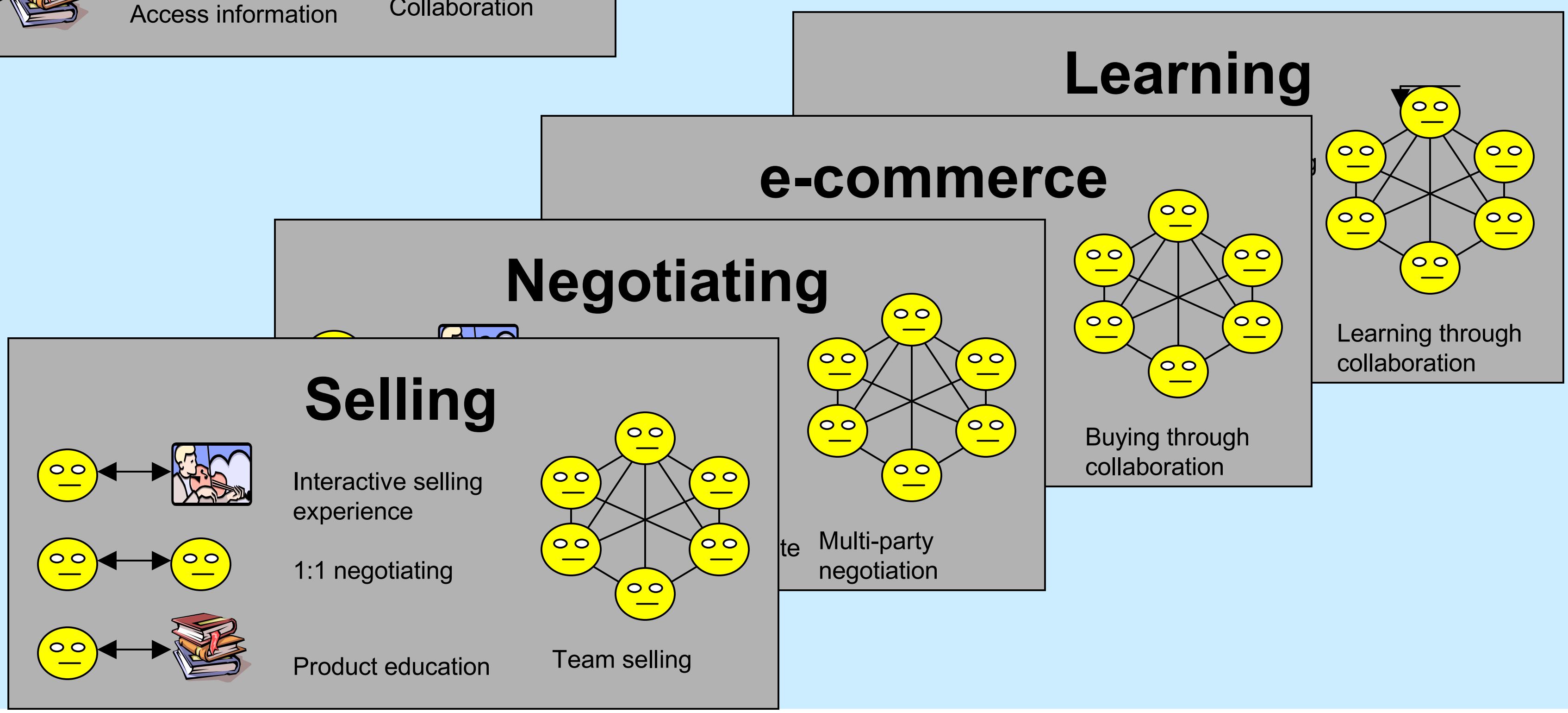
+ New forms of interaction
+ New forms of content
+ New forms of assessment



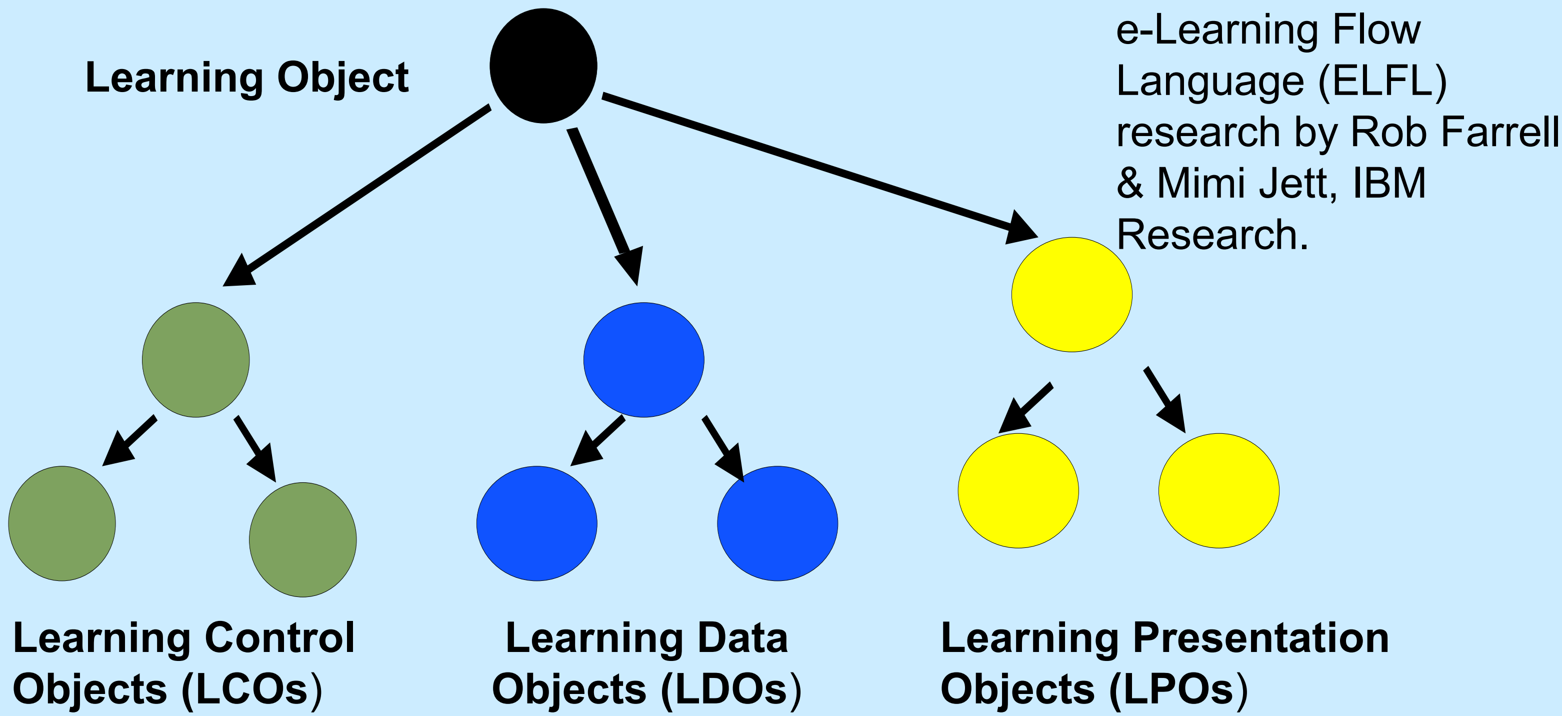
Models for Human Interaction



- Standards-based methods for representing single party or multi-party interactions as data, not code
- Run-time environment for interactions, separated from the content
- Start with learning
- Generalize into tools for web-based experiences

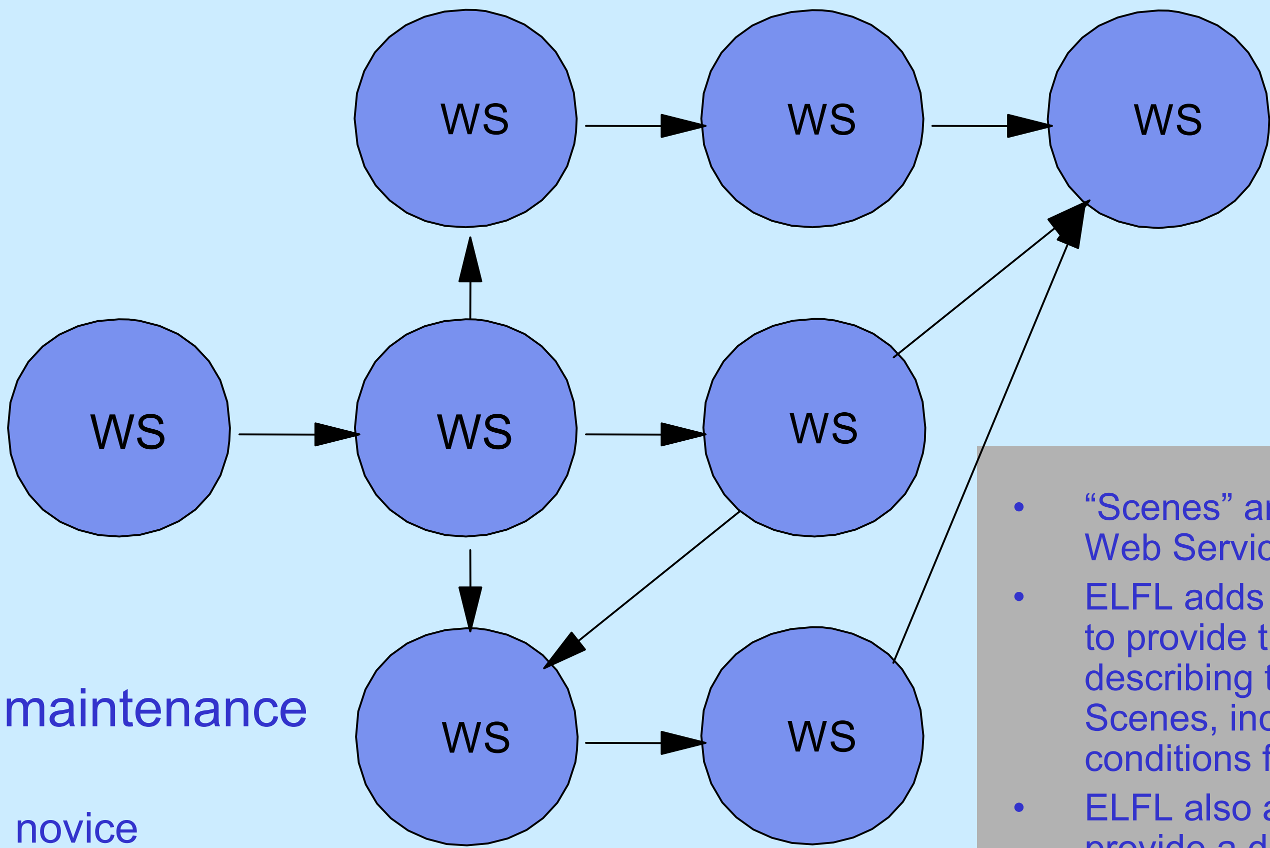


Learning Object Model



Learning Control Objects: XML and/or scripting to select/sequence objects across pages and update learner state.
Learning Data Objects: learning objectives, learner state, media + learning objects (IEEE LTSC, IMS)
Learning Presentation Objects: XSL transformations to layout groups of objects on a page and style pages with WSXL (XLINK) event processing for specifying event-driven updates (SCORM/IEEE/IMS)

Example of Navigation in Learning Space (2)

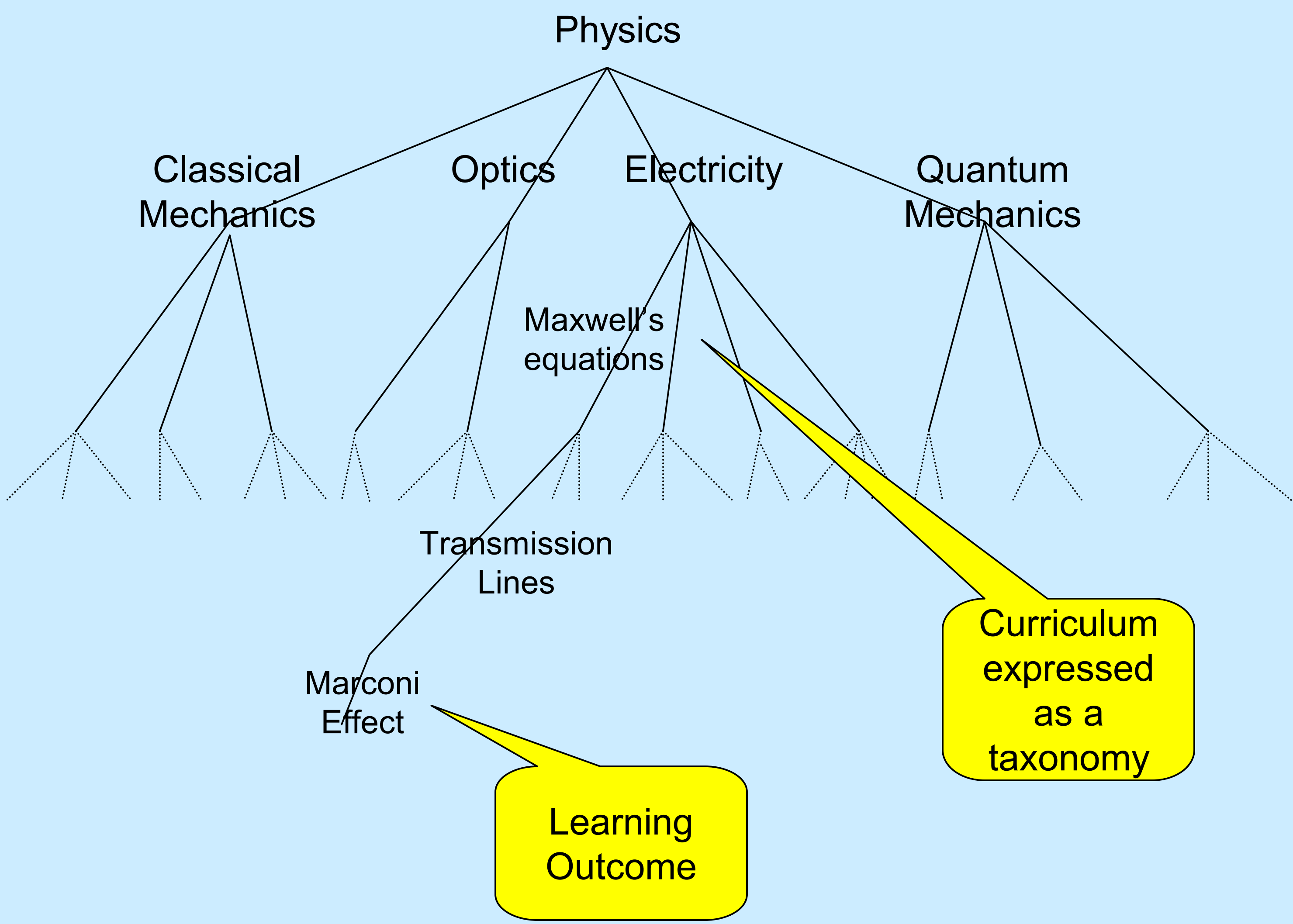


e.g. Aircraft maintenance scenario

- expert, novice
- mechanic, inspector, manager
- expert's footprints guide the novice

- "Scenes" are in fact individual Web Services
- ELFL adds extensions to WSDL to provide the mechanisms for describing the properties of the Scenes, including pre/post-conditions for branching
- ELFL also adapt WSFL to provide a description of the graph topology for a particular traversal of the Scenes
- XSL enables skinning for common look and feel

Example of Structuring the Learning Space



Summary

- Learning as an interaction space among individuals, teams, and information
- Dimensions of interaction space
- Computer's role in mediating these interactions
- Generalization of interactions beyond learning
- Integration of interaction tools into a framework for human interactions in organizations
- Converging with the mainstream
    - e-Learning as an application of mainstream technologies
    - Death of proprietary standards?
- "A Machine for Thinking In"
    - Cf LeCorbusier – a framework for collective thinking