Balancing Objectivist and Constructivist Pedagogies for Teaching Emerging Technologies: Evidence from a Scandinavian Case Study

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ABSTRACT

This paper describes some of the problems that IS faculty encounter, when they attempt to teach emerging information technologies. We conceptualize these problems as a dilemma: between an objectivist perspective for teaching the basics of tools and syntax and a more enlightened, constructivist and socio-cultural pedagogical perspective that emphasizes principles and application of the technology. In this paper, we explore this dilemma drawing on a specific case study, where the authors were engaged in teaching eXtensible Markup Language (XML) at a Scandinavian institution. We follow a multi-method research approach drawing on our own critical reflections throughout the term, and feedback obtained from the students at the end of the term. The data indicates that for teaching emerging technologies, educators face challenges at several levels including class content, class conduct, and designing of educational experiences. The students appear willing to pay the cost of fragmented approaches for the benefit of getting an early start on learning emerging technologies. Integrating these with perspectives afforded by the learning theories leads us to strategies that may be useful for designing and conducting courses in emerging information technologies.

Keywords: emerging technologies, balancing pedagogies, objectivist, constructivist, evolutionary stance, case study

1. INTRODUCTION

The already frenetic pace of change in information technology keeps accelerating. Over the last few years, foundational information technologies have undergone major upheavals. Programming technologies have moved from a predominantly structured approach to an object-oriented approach [Rational 2004]. A similar change is seen in networking technologies, which are moving to broadband and wireless technologies [Broadband 2004]. In the field of databases, this change is seen in the move from relational models to object-relational models [Object-Relational 2004], and more recently, to document databases [XML 2004]. Yet another example that most of us have experienced over the last few years is the rise of the web as the dominant interface and the consequent rise of e-commerce technologies and the need for information security [W3C 2004].

In a recent compilation, Day and Schoemaker [2000] describe several characteristics that signify emergent (as opposed to established) technologies. A key characteristic of these technologies is 'ambiguity,' which is manifested in several dimensions, including an uncertain knowledge base, new markets, evolving standards, and new use patterns. Examples of these include wireless technologies, extensible markup language, and web services. Sidebar 1 defines the term and outlines its key characteristics.

A corresponding trend is often noticed – lack of qualified personnel to effectively exploit these technologies in meaningful ways – leading to increasing demands on academia to educate students. In addition to increasing offerings of executive education courses [Vitiello 2001] and web-based training materials [WebBasedTraining 2004], IS departments in several universities have revamped their curricula to accommodate these changes. There is greater demand from students and businesses alike for state-of-the-art education in emerging information technologies that will allow them to participate more effectively in the new information economy. The Information Systems disciplines are being called upon to address these educational needs. The hyper-accelerated speed of change in IT is, however, allowing educators little time to reflect on these emerging technologies posing the danger that educational efforts will focus solely on concerns such as tools or syntax, at the cost of underlying principles or its meaningful application. Further, IS faculty face other concerns such as varying degrees of preparedness, difficulties in obtaining software, and balancing teaching and research.

Sidebar 1. Emerging Information Technologies

Day and Shoemaker (2000) define these as innovations with the potential to significantly change the creation, storage, manipulation or transmission of information; and in the process, create or transform industry or markets. They exhibit the following characteristics: (a) uncertain architectural standards, (b) evolving understanding of functional benefits, (c) formative regulatory standards, (d) speculative use patterns, (d) incomplete market knowledge, (e) embryonic industry structure, (f) new market players, and (g) emergent and fast changing rules of the game.

Against this backdrop, several interesting questions can be identified, related to concerns such as the need to educate the educators, insertion of emerging technologies in the IS courses, and methods for teaching such course content. In this paper, we explore some of these concerns drawing on a specific experience that we shared while teaching a course titled 'Document Management with XML' at a Scandinavian institution during the year 2000. Treating the course experience as a single case, we use multiple data sources such as our decisions about the course, products generated through the conduct of the course, critical reflections from the educators through the term, and student feedback we gathered at the end of the term. Our analysis of this data is informed by writings about pedagogical practices and theories of learning.

The remainder of the paper is organized in five sections. Section two reviews pedagogical practices and theoretical perspectives with a view to understanding their applicability to teaching emerging technologies. Section three outlines the research methods followed for the study. In section four, we discuss the case study, teaching the course in XML at a Sandinavian institution. Sections five and six present instructor reflections and student feedback respectively. In section seven, we integrate the two with learning theories to derive recommendations for learning emerging information technologies, and provide some concluding remarks.

2. THEORIES OF LEARNING

At least three different schools of thought may be discerned from the various theories proposed over the last several decades. These include (a) the objectivist camp [Jonassen 1993, McKeachie 1990], (b) the constructivist camp [O'loughlin 1992], and (c) the social-cultural camp [Iran-Nejad et al 1990]. The first argues that knowledge resides with the instructor and students act as passive recipients of this knowledge. The lecture mode of teaching characterizes this school, which espouse the role of an all-knowing instructor.

The second group of theories – the constructivist camp – argues for an individual construction of knowledge that is aided by the instructor. This school of thought [Piaget 1929, Bruner 1966], assumes that each individual constructs his or her own reality of the objective world [Yarusso 1992, Leidner and Jarvenpaa 1995]. The theories in this camp, therefore, argue that learning is an active process, in which students construct new ideas or concepts, while engaged in new experiences, based on their current and past knowledge [Bruner 1966]. The goal of teaching, then, is to allow formation of abstract concepts [O'Laughlin 1992], not feeding these externally to the student. The concept of cognitive structures is, therefore, central (e.g. [Piaget 1929, Bybee and Sund 1982]). Another set of theories in this camp emphasizes the 'group' over the individual. Conversation theory [Pask 1975] suggests 'teachback' as the critical approach, where learning occurs through conversations about a subject matter.

The third group of theories – the social/cultural camp – suggests that knowledge is not abstract; instead, it is rooted in context and culture i.e. it is situated. This school of thought (e.g. [Lave 1988, Lave and Wenger 1990]), disagrees with the constructivist view that the goal of learning is formation of abstract concepts. Instead, it argues that knowledge cannot be divorced from the historical and cultural background of students [O'Laughlin 1992, Leidner and Jarvenpaa 1995]. It argues that events that are meaningful and situated in context result in deeper and more elaborate processing, leading to the construction of personal knowledge, meaningful to the individual [Iran-Nejad et al. 1990]. An important theory in this camp is situated learning by Lave [1988], who argues that learning as it normally occurs is a function of the activity, context and culture in which it occurs (i.e. it is situated). Lave and Wagner [1990] call this process, which they argue is unintentional rather than deliberate, as 'legitimate, peripheral participation.' Brown et al. [1989] emphasize the idea of cognitive apprenticeship. Argyris [1976] suggests double-loop learning, and Schön [1983] uses the term reflection. Feedback from an expert serves to guide the apprentice to discover context-specific ways of working, without clarifying or encouraging discovery of any general concepts. A major premise of the social/cultural camp, thus, is that knowledge is not only individual, but also rooted in context, that is, situated.

2.1 A pedagogical dilemma

The above choices present a considerable dilemma for the instructor, particularly for a course laden with information technologies. On one hand, the instructor must present material that the students are expected to absorb. On the other hand the instructor may wish that the students learn underlying principles and are able to understand and apply these technologies given a problem. The different pedagogical schools of thought support these objectives to varying degrees (see Figure 1). The learning of basic tools and syntax, which must be presented by the instructor, is best supported following the objectivist camp. Learning the underlying principles requires that students construct their own stock of knowledge, arguing for a constructivist approach. Finally, interaction with other participants, while instantiating and applying the principles learned to specific problems argues for a social/cultural approach. Figure 1 outlines this mapping.

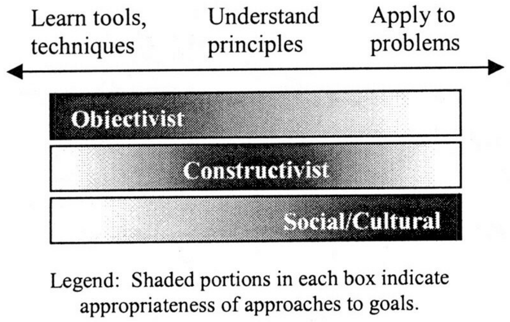


Figure 1. Mapping Teaching Approaches to Goals

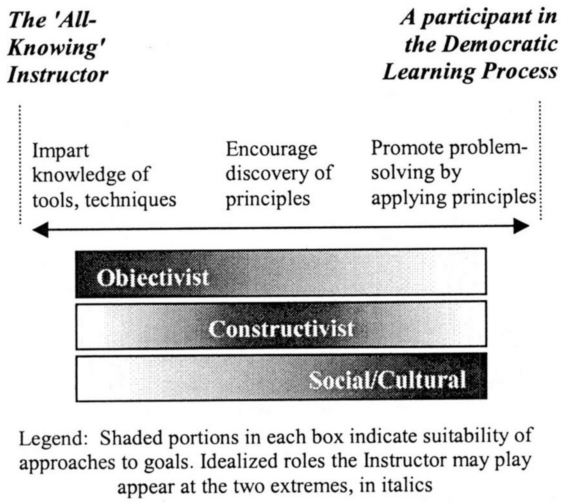


Figure 2. Mapping Teaching Approaches to Goals

The broad mapping indicates that a pedagogical practice for teaching information technologies must manage to integrate all three camps in a concerted effort. Prima facie, this integration of approaches presents a difficult challenge, as the roles the instructor must play - an all-knowing instructor vs. a participant in a democratic learning process - can be in conflict. The pedagogical dilemma this presents is illustrated in figure 2.

While the general form of this dilemma is applicable to teaching most information technologies, the challenges are exacerbated for teaching emerging technologies. There are two primary reasons for this. First, there is a tendency to emphasize tools and techniques when teaching emerging technologies. More mature technologies allow focus on 'underlying principles' with teaching resources that support understanding of these principles, thereby reducing the burden on the instructor in the objectivist camp. Second, unlike mature technologies, it is difficult to focus on learning problem-solving with an emerging technology because good examples of practical application are considerably more difficult to find.

The pedagogical dilemma outlined above, therefore, represents a key concern for teaching emerging technologies: on one hand, the need to teach the basic technological concepts, including syntax and tools, and on the other, the desire to facilitate the learning of problem-solving possibilities with the new technology, focusing on underlying principles. Finding the right balance is difficult. As a consequence, the roles and approaches the educator adopts are open to considerable experimenting. To explore these concerns, we adopted a case-based research approach. We describe below the methodological bases for this research approach.

3. RESEARCH METHOD

Because our intent was to understand a complex phenomenon where there is either no dominant theory or there is a plethora of conflicting theories, we chose a research method that represented a mix of case study research [Yin 1989] and action research [Orland-Barak 2004]. The overall approach, thus, does not involve the testing of hypotheses from previously established theories. Instead, our goal was to question the lack of a theory and attempt to build the rudimentary foundations of a theory as a set of propositions [Eisenhardt 1989].

The first component of our research approach can be characterizes as 'case study,' which is a form of qualitative descriptive research that examines intensely an individual or a small participant pool to understand or draw about a phenomenon in a specific context with emphasis on exploration and description [Colorado State 2003]. A case study focuses on the collection and presentation of detailed information about a particular subject, group or phenomenon [Yin 1989, 2003]. The term 'case study,' thus, is used to describe a unit of analysis or a research method that does not rely on a large sample size [Darke, Shanks and Broadbent 1998]. Instead, it can build on even a single, rich, dense experience of a phenomenon [Duke 1965]. Case study research is the most often used qualitative research method used in information systems [Orlikowski and Baroudi, 1991; Alavi and Carlson, 1992]. Yin [1994] defines a case study as an empirical inquiry that "investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" [Yin 1994, p. 13]. Following Walsham [1993], our stance was that of an interpretive, in-depth case study, instead of a positivist case study like that proposed by Yin [1994] and Benbasat et al. [1987].

The second component of our method was action research, which Rapoport [1970, p. 499] defines as contributing both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework. Intervention is a key element of action research [Avison et al. 1999]. The researcher is an active participant in an action research process, which is infused by theoretical perspectives that the researcher elects to bring to the conduct of research [Baskerville and Wood-Harper 1996]. The intervention in our case was the specific design of the course that was deployed in the setting described in this paper. The collaborative aspect of action research was realized in the form of collaboration between students and teachers. And the theoretical perspectives brought to the research process were the different theories of learning outlined in the previous section. Action research has been accepted as a valid research method in applied fields such as organization development and education [Johnston and Proudford 1994].

Finally, the specific data collection procedure followed for our research was a multi-modal one, where we attempted to balance the results of data collected from the students against reflections based on our own engagement with the phenomenon [Colorado State 2003]. The participants in the research process, thus, included both the instructors and the students. Our mixed method approach was, thus, operationalized as reflections from researcher-instructors throughout the semester, followed by a survey that captured the student impressions at the end of the semester. The use of multiple modes of data and the different times at which these were articulated, collected and analyzed, thus, allows us bring a higher level of reliability to the set of propositions offered in the conclusion. In the absence of a dominant theory to determine the ideal content or structure for a course teaching emerging technologies, the research method outlined above was considered appropriate that addressed our intent to uncover dimensions and constructs of interest.

4. CASE STUDY

A course titled Document Data Management, as an instantiation of the Advanced Database Management course, was offered during Spring 2000 at a Scandinavian university, as part of the undergraduate degree program in Information Systems. The course was co-taught by the authors, a visiting faculty (in English), and a full-time faculty (in Norwegian). The students enrolled in the program were obtaining the first undergraduate degree. They had basic knowledge about database management from a preliminary course that covered topics such as conceptual modeling, relational data model, normalization, structured queries etc. The advanced database course was, thus, designed to build on this basis, and to introduce XML in the context of document data management.

Content: The central theme for the course was Document Data Management. The course included topics that presented XML and related technologies as another alternative for structuring, displaying and managing data in the form of documents. The content was organized to allow anchoring to known concepts from a traditional database course. For example, the discussion on Document Type Definitions (DTDs) was supplemented with discussion on relational database table designs, that on XML Query Languages (XQL) was supplemented with SQL, and that on XML Linking Language (XLL) was supplemented with primary key – foreign key dependencies. In addition, software demonstrations were facilitated in computer labs. The incomplete XML technologies were difficult to force-fit into the well-developed knowledge framework in the database field. Table 1 below shows the contents, comparing it against a possible advanced database course.

Table 1. Course Contents

Topic	**Advanced Databases (Traditional)**	**Document Management with XML**
Database models, Data dictionary	O-O and Object-Relational Databases	Document Structures and DOM
Database Languages and Systems	Advanced Query Techniques	XML Query Language
Client Server Architecture	Client/Server Databases	Integrated with XML
Missing	*Missing*	Rendering, Transform (Xpath, XSL)
Data Integrity, Security	Advanced Transaction Processing	*Missing*
Distributed database systems	Physical Database Design and Distributed Database Design	Schemas, Custom markup languages
Database Administration	Data and Database Administration	*Missing* (Native XML Databases)

To support delivery, several books were consulted, which focused on basic technological rules and syntax; as were resources on the Web, which had a technical focus. Tools used included: XML-Spy™ for editing XML, DTD, XSL documents, Query-view™ for querying XML documents, and Microsoft Internet Explorer™ for parsing and displaying the XML documents.

Project: The course was built around a project that required using XML and related technologies for managing documents. Since most students had no direct access to businesses as places of work, the project consisted of creating a document management system for teaching-related material created by faculty members at the IS department. The documents of interest were identified as lectures, exams and other relevant content. Using this experience as the vehicle, the students would learn core XML technologies such as DTDs, XSL, XLL, XSchema and others. The first part of the project involved creating a small document management system for an instructor. Each student group was assigned to a different instructor for creating document type definitions (DTDs) and sample instance documents (XML) for (a) class handouts, (b) course syllabi, (c) assignments and projects, and (d) exams and quizzes. This required the project groups to engage in requirements gathering, modeling and implementing the core XML technologies. The second part of the project was dictated by the nature of the XML technologies when applied to content management, that is, standardization of document types. This required project groups to reconcile the document type definitions they had created for different instructors to create a standard for the entire department. Table 2 below summarizes these learning experiences.

Table 2. Project-based Learning Experiences

Project : Part 1 Course Document Management System for an Instructor		
Task	**Technology**	**Purpose**
Requirements Gathering by each group		
Create document definitions	Document Type Definitions (DTDs)	Model user-specific standards
Create sample documents	Instance (XML) Documents	Test appropriateness
Project : Part 2 Infrastructure for a Course Content Management System at the Department		
Task	**Technology**	**Purpose**
Negotiation among Groups towards Standardization		
Create component definitions	Document Type Definitions (DTDs)	Identify core components
Create document definitions	Hierarchies of DTDs	Model standard (school-wide) definitions
Create sample documents for different users	Instance Documents (XML)	Validate against individual requirements
Create styled documents for different users	Extensible Style Sheets (XSL)	Render using individual preferences

Conduct: The course included several sessions with a traditional lecture format; and some hands-on sessions to demonstrate tools and illustrate the syntax. Specifically, the former discussed examples of syntax and how different elements of XML fit together. The latter allowed students opportunities to test these rules with tools. To promote understanding of principles, that is, for moving towards the more constructivist and social/cultural pedagogical camps, a few different techniques were used during the lectures. One was teachback [Pask 1975], where students worked in pairs, with one student teaching another. Another technique involved use of tools that allowed discovery of intermediate products, with which the students could create their own mental models [Bruner 1990]. A third technique was the use of teams that were required to communicate with each other [Carroll 1990, Lave and Wegner 1990]. A few classes were devoted to project discussions led by different teams. Since the project involved standardization of document structure, these in-class sessions also promoted interactions across teams. Finally, guest lecturers were invited from a company that was attempting use of XML for web publishing, and one instructor-lead session was devoted to discussion of use and application of XML.

5. REFLCTIONS FROM INSTRUCTORS

The co-teaching format allowed each instructor to step back and reflect on previous student contact. Following the research method outlined earlier, this provided the first mode of data collection for the research process. These were articulated during the semester, that is, while the researchers were engaged with the case. Several recurring themes emerged from these reflections.

5.1 Movement between extreme levels of abstraction

A repeatedly difficult part of the course was the constant movement between extreme levels of abstraction. As an example, consider the discussion about treating documents as data and arguing for the separation of content and presentation, i.e. a fairly abstract level. This was immediately followed by a mapping of the idea to XML documents, XSL stylesheets and Document Type Definitions (DTDs) and their syntax. Due to the lack of accepted conceptual models of documents, an intermediate representation between the two perspectives was not available, requiring wide jumps between the extreme levels of 'motivation' and 'syntax.' Similar movements were observed on several occasions throughout the course.

This movement can be traced to multiple key characteristics of Emerging Information Technologies (see Sidebar 1), such as formative standards and speculative use patterns. In the absence of intermediate levels, large leaps are required between the two extremes, presenting considerable challenge for structuring the learning experiences. Other instances of emerging IT exhibit similar features. As an example, consider object-oriented programming and its specific implementation with a language and environment such as Java. The gap between concepts (such as abstraction) and implementation platform (such as Java classes) can be wide. This gap can reduce as experience is accumulated and intermediate principles are articulated. Until then, however, the golden middle continues to elude, making the teaching of emerging IT a challenging proposition.

5.2 Lack of cogent explanations of principles

The missing, intermediate levels of abstraction were manifested as lack of principles underlying the technology. Specifically, no cogent rationales or explanations were available for several component technologies, the most notable being XSL Transformation as specified in the XSLT draft from January 2000[1]. Lack of explanations of underlying concepts contained in these drafts combined with implementations that differed from the standard made learning quite difficult. This was further confounded by the varied and incomplete explanations contained in various books, which focused on the technology at the cost of the underlying principles.

In addition to the factors mentioned above, two other characteristics of Emerging Information Technologies (see

Sidebar 1) contribute to this lack of principles – uncertain standards, and fast-changing rules. Without clear articulation of these, the rationale for varied implementations of concepts remains murky. With formative and evolving standards, these rationales and associated principles can undergo significant changes. For emerging technologies, therefore, the instructor tends to be the sole moderator for providing this rationale. As another example, consider the event-processing model for Java, which has undergone considerable change in successive versions of the environment, requiring changes in principles and rationale. As the technology and standards become stable, this challenge is mitigated, with more cogent rationale and accepted principles. Until relative stability is attained, however, the lack of explanations continues to be a challenge to the instructors.

5.3 Lack of guidelines for use of the technology

The focus on technology also did not extend to useful guidelines for practical use of the technology. The core ideas behind the XML technologies are elegant and simple, in many ways easier than relational databases. Unlike traditional databases, which require a good understanding of concepts such as relational theory and normalization, tag-based XML is fairly easy to grasp and easier to visualize. It is easy for the students to understand the logic behind XML. However, there are no guidelines for concerns such as what constitutes a good document structure nor are there established guidelines for understanding choices that need to be made for XSL rendering and transformations. This lack of guidelines for practical use of the technology was another concern. Without such guidelines, it was easy to get bogged down into trivial details at the expense of important design decisions.

The lack of guidelines can be identified as a direct consequence of several characteristics of Emerging Information Technologies (see Sidebar 1) including evolving benefits and speculative use patterns. For example, two views of the XML technology had emerged during the time the course was taught. One focused on content structuring and the other on treating XML as a higher-level transport mechanism. Focusing on one benefit versus the other and speculating about its eventual use pattern would have resulted in different operationalization of 'guidelines'. As these characteristics evolve, the shifting nature of practical guidelines poses a significant challenge to the instructors and students. As another example, consider the use of Java frameworks in a manner that has been called the 'hollywood principle' (the framework will call your code, not the other way around) [Vlissides 1996]. Such interesting articulations of general guidelines require reflection and experience. Until they become available, the instructor is forced to adopt an 'anchor-and-adjust' mode trying to apply guidelines from related established technologies.

5.4 Losing the forest for the trees

The students and instructors were overwhelmed by the need to resolve the many technical issues about syntax, standards, current implementations and the differences between implementations and standards for XML, XSL, XLL and XQL[2]. Many of these require different mental models (e.g. an XML instance document which places a premium on element ordering versus an XSL document that uses a context-driven model of content rendering). This made it difficult for the students to understand, retain and manipulate a common mental framework as the focus shifted from one component to another.

This problem can be considered to be a consequence of three key characteristics of Emerging Information Technologies (see Sidebar 1) – uncertain architectural standards, formative regulatory standards and incomplete market knowledge. Together, they lead to the creation of multiple components (from different vendors) that can often overlap in functionality and intent, leading to confusing mental models of the overall technology landscape. Different components can also be subsumed in favor of new ones. As an example consider the deprecation[3] of several alternatives in favor of the XML schema standard. This problem can be particularly acute for macro level innovations that have complex structural relationships with other technologies as XML does. As another example consider the Java environment, which needed to establish bridges to existing components, such as ODBC and the HTTP layers; and the J2EE framework with its components including Applets, Servlets, JSP, Beans, EJB and JDBC that a student must learn to use together. As the technology matures, it is conceivable that individual components are subsumed under different perspectives allowing an instructor teaching system design to focus on, say, Beans and EJB to teach the J2EE framework. Parallels can be drawn for say, the XML set of technologies, (e.g. XML and XQL under database, XLL under Web development). This can allow a course in XML to focus on schemas, RDF and advanced design topics such as Schemas as well as content manipulation with XSL. Until such maturing occurs, ensuring that the student acquires an awareness of different components remains a problem for teaching that technology.

5.5 Mismatch between evolving standards and tools

The task of arriving at cogent mental models was further exacerbated by the incomplete standards and their lack of correspondence to even more incomplete implementations. With new standards drafts appearing during the term (January and February 2000 for XSL), and working group meetings of others (XSchema, during March 2000), it was decided that the efforts to understand and prepare course content would be postponed to a just-in-time process to ensure relative accuracy. Yet another factor that complicated the matters were the tools, which had implemented in many cases, an earlier version of the standard that had since progressed to include new elements and discard some of the implemented ones. This prompted a number of discussions in class, which included statements such as 'this is supposed to work in principle.'

Such mismatches are a common occurrence as an Emerging Information Technology (see Sidebar 1) is introduced into a market. With evolving standards and new entrants in an embryonic industry structure, implementations are released by IT vendors without waiting for the final resolution of standards. The problem can be severe when a coalition of market players participates in standards-building, because of competing product releases. XML and allied technologies are, therefore, more severely affected by this problem. On the other hand, a technology, such as Java, proposed by a single firm, and embraced by the market, can be relatively easier because of early releases of the 'standard' implementation by the proposing vendor (i.e. Sun). The problem of evolution and resulting mismatch between standards and tools are however witnessed in both situations. Instructors face a challenge in discussing these because of the conflicting demands of 'teaching something that works, i.e. tools available' versus 'teaching emerging ideas for which tools are not yet available'. Clearly, as the standards stabilize, the problem dissipates with availability of tools that match standards. For more mature technologies, the problem can be observed for addition of new features e.g. a DBMS such as Oracle may be extended to include XML generation capabilities[4]. As the marketplace evolves and standards become more stable, the intensity of the problem can be managed effectively. Until this stability occurs, though, teaching in this turbulent environment remains a significant challenge for the instructor.

5.6 Extensive experimentation

The mismatches required extensive trial-and-error for learning the tools and the synthetic rules/processes embedded in these tools. Without the benefit of cogent principles or accepted underlying models, no anchor points were available for understanding these tools and techniques. To protect the students from the steep learning curves associated with these, the instructors spent time exploring different explanations of implementations and rationalizing these for the students.

The problem of 'extensive experimentation' and sometimes, improvisation, can be viewed as the visible consequence of the other concerns discussed so far. Without the benefit of established standards, guidelines, marketplace, tools or background knowledge – the students look to the instructor to provide all these elements. For the instructor as well, the conflicting sources represent an array of fragmented information, each representing the viewpoint of a different stakeholder. Without credible source of authority, it often falls upon the instructor to engage with these diverse sources, and integrate these in a cohesive framework. With greater experience, and with a strong reliance on the principle of anchor-and-adjust, the instructor can overcome this challenge. For example, teaching XML as an advanced form of data management was key to structuring and teaching the course in the case outlined. Until the technology matures, the significant demands on time and effort that this extensive experimentation requires continue to be a significant challenge. Table 3 summarizes these reflections.

Table 3. Reflections from Instructors

Movement between extreme levels of abstraction
Lack of Cogent Explanations of Principles underlying the Technology
Lack of Guidelines for Practical Use of the Technology
Losing the Forest for the Trees
Mismatch between Evolving Standards and Tools
Extensive Experimentation

6. STUDENT FEEDBACK

A second, complementary, source of data was collected at the end of the term as student feedback. Because of its exploratory intent, no a priori hypotheses were postulated. Most items in the questionnaire were adapted from prior work [Chiu et al. 2003] following a Likert scale from Strongly Agree (1) to Strongly Disagree (6). The questionnaire (Appendix A) was administered to 33 students. Table 4 shows descriptive statistics for the data (lower scores

Table 4. Descriptive Statistics for Responses (1 Agree – 6 Disagree Likert Scale)

	Item	Avg.	S. D.
21	Overall, I am satisfied with the course. *(Dependent Variable)*	2.4	0.929
1	I learned that managing documents is an advanced form of data management.	2.4	0.899
2	I see the connection between this course and the basic Database course	3.1	1.387
3	The course focused on tools and syntax at the expense of theory and principles.*	3.7	1.032
4	The course focused on theory and principles at the expense of tools and syntax.	3.1	1.044
5	The course provided sufficient examples of the technologies covered.	3.1	1.223
6	There was a mismatch between theory discussed in class and the tools available for using the theory.*	2.8	0.965
7	The new and evolving standards for XML technologies were difficult to understand and use.	2.8	1.192
8	It was difficult to integrate the different technologies such as DTD, XML, XLL, XSL etc.	3.1	1.208
9	I believe that this course using XML was of more value to me than a traditional advanced database course.	2.3	1.212
10	I believe that a traditional advanced database course would have been of more value to me	4.3	1.372
11	The course provided sufficient guidelines about how to use the new technologies for solving problems.	3.3	1.153
12	The course emphasized discussions during class instead of presentations from teachers.	2.4	0.759
13	The hands-on lab sessions were helpful in understanding the concepts.	2.1	1.294
14	The projects provided sufficient opportunities to practice the concepts and principles discussed in class.	2.8	1.193
15	The course emphasized group work at the expense of lectures.	2.7	0.924
22	The College should have courses in the technological front, and accept courses with less structure **.	2.0	1.075
23	The College should wait till a new technology is stable, and fully working as expected before offering courses.*	4.8	1.278

* Reverse worded. ** Items 16 – 20 required textual answers.

indicate stronger agreement). The summary question: 'Overall, I am satisfied with the course' resulted in a mean response of 2.4 with a standard deviation of 0.929, indicating the students' positive disposition.

An exploratory factor analysis was performed on all items, except the summary question (21, Course satisfaction), to discover any latent factors. This was appropriate because the survey was not intended to validate relationships across constructs[5]. An exploratory factor analysis with 25 iterations, following no rotation and excluding pairwise cases, resulted in five groups. Two items were not mapped to any factors. Table 5 shows the results.

Interestingly the analysis suggested factors (other than the first) that resembled the reflections articulated by instructors during the term. To assess their contribution to the dependent variable – satisfaction with the course – a regression model was run. The regression suggested that the most important factor was not the various concerns but rather, the 'perceived value' of the course (adjusted R-squared of 20.7 with a Beta of 0.483 at a significance level of 0.01).

Table 5. Results of Exploratory Factor Analysis

Factor 1: Perceived Value of the Course	
01	I learned that managing documents is an advanced form of data management
02	I see the connection between this course and the basic Database course
07	The new and evolving standards for XML technologies were difficult to understand and use *
09	I believe that this course using XML was of more value to me than a traditional advanced database course
10	I believe that a traditional advanced database course would have been of more value to me*
22	The College should have courses in the technological front, and accept courses with less structure
23	The College should wait till a new technology is stable, and fully working as expected before offering courses*
Factor 2: Learning Tools and Syntax	
03	The course focused on tools and syntax at the expense of theory and principles
08	It was difficult to integrate the different technologies such as DTD, XML, XLL, XSL etc.*
13	The hands-on lab sessions were helpful in understanding the concepts
Factor 3: Learning Underlying Principles	
04	The course focused on theory and principles at the expense of tools and syntax*
05	The course provided sufficient examples of the technologies covered
Factor 3: Learning Application of Principles	
11	The course provided sufficient guidelines about how to use the new technologies for solving problems
14	The projects provided sufficient opportunities to practice the concepts and principles discussed in class
Factor 5: Mismatch between Principles and Tools	
06	There was a mismatch between theory discussed in class and the tools available for using the theory

* Reverse worded, that is, reverse correlation against other items in the factor

To better understand how individual items contributed to course satisfaction, a simple, stepwise regression analysis was also performed without the item grouping suggested by the factor analysis. At the significance level 0.05, two items were found to be important (see Table 6), explaining a little more than 54% of the variation in the dependent variable. Of these, the first, question 9, was mapped to the factor Perceived Value, the second, question 5, was mapped to the factor Learning Underlying Principles (see Table 5). The students' eagerness to learn a new technology (question 9), thus, contributed almost half of their satisfaction with the course.

Table 6. Relating Items to Course Satisfaction
(significance level 0.05)

Item	**Adj. R^2**	**Beta**
9. I believe that this course using XML was of more value to me than a traditional advanced database course	47.8	0.57
5. The course provided sufficient examples of the technologies covered	54.5	0.31

Relaxing the significance level to 0.1 resulted in addition of three more items which, together with the two above, explained more than two-thirds of the variance in course satisfaction (see Table 7). Of these, the first, question 6, was mapped to the factor Mismatch between Principles and Tools, the second, question 22, was included in the factor Perceived Value, and the third, question 13, was mapped to the factor Learning Tools and Syntax (see Table 5). Interestingly, in-class sessions (question 12) and project experiences (question 14) were not strong contributors.

The results indicate a consistent theme. The course satisfaction was tied to perceptions about value. Concrete examples of use of the technology contributed to satisfaction with the course, whereas the difficulty in understanding and using the evolving standards contributed to dis-satisfaction with the course. Interestingly, responses to question 23 (see table 5), which was not correlated with course satisfaction, still indicated a very strong preference for courses with emerging technology without waiting for stability. The attitude was mirrored in question 22 (see table 4), which echoed this preference for courses on the technological front in spite of less structure.

Table 7. Relating Items to Course Satisfaction
(significance level 0.1)

Item	**Adj. R^2**	**Beta**
9. I believe that this course using XML was of more value to me than a traditional advanced database course.	47.8	0.418
5. The course provided sufficient examples of the technologies covered	54.5	0.264
6. There was a mismatch between theory discussed in class and the tools available for using the theory*	59.1	-0.305
22 The College should have courses in the technological front, and accept courses with less structure.	63.9	0.300
13. The hands-on lab sessions were helpful in understanding the concepts	67.2	0.210

* Reverse worded.

7. DISCUSSION

The learning theories were used as an interpretive lens in an integrative, retrospective analysis to derive preliminary recommendations for teaching emerging information technologies that may be subjected to further empirical evaluation. Both sources of data suggested application of multiple learning theories, with the need for emphasis on tools, syntax, principles as well as examples of application. Therefore, the overarching theme that emerged from this retrospective analysis was the need to view the semester as an experience where the epistemology of learning would evolve. This evolution represented an alternative to the dilemma (see section 2). The recommendations we propose follow from this analysis, and are grouped in three areas – structure, content and roles. Below, we refer to instructor "reflections" in quotes, and indicate correspondence against questions used for student feedback in by referring to the tables (in parentheses).

7.1 Retaining flexibility in the course structure

Course structure refers to the arrangement of topics through the term. Student feedback was clear that some uncertainty in the course structure is tolerated for a new technology (Item 23, Table 4). Though an anchor-and-adjust strategy effort was used to design the course (see table 1), it was difficult to present the XML technologies in a manner that would not lead to a "losing the forest for the trees." As the semester progressed, students engaged in projects, which required dealing with ill-defined requirements and working in teams. The course structure was, therefore, deliberately allowed to remain flexible to allow discussions of concerns that arose from the project. The students indicated that project experience was valuable (Item 14, Table 4). Though it did not contribute significantly to course satisfaction (see Tables 6 and 7), it allowed evolution towards greater student participation and control over the learning process. The evolution was hindered by a "mismatch between evolving standards and tools." This required hands-on lab sessions, which were considered valuable (Item 13, Table 4) by the students. On the other hand, class discussions that invited student participation were not perceived as valuable (Item 12, Table 4). Together, instructor reflections and student feedback suggest that evolving course structure was not perceived as a valuable element, but in fact, resulted in student experiences that eventually lead to favorable learning outcomes.

Drawing on the above, we argue that flexibility is an important aspect of course structure for emerging technologies. For the XML course, anchoring the course to an advanced database course allowed the instructors to retain the structure as changes were introduced. Course elements such as class discussions and projects can facilitate this balance between structure and flexibility. Specifically, techniques such as teachback [Pask 1975] that are better at facilitating the formation of cognitive structures [Piaget 1929] as well as scaffolding and providing varying levels of assistance [Vygotsky 1978] are appropriate for this evolution. As students become familiar with the fundamentals, situated approaches that focus on specific applications of the knowledge [Lave and Wagner 1990] can also be attempted. The recommendations for course structure, based on the above discussion, may be summarized as:

- the course structure should have varying levels of flexibility through the duration of the course
- the instructors should engineer this evolution with appropriate course elements (e.g. projects) and practices (e.g. teachback)

7.2 Balancing principles with tools in course content

Course content refers to the choice between focusing on tools/principles on one hand, and their application to different situations on the other. This was reflected in the importance the students attached to obtaining examples (Item 5, Table 4) and the hands-on lab sessions (Item 13, Table 4). To facilitate this grounding, "extensive experimentation" was needed from the instructors. This burden is often heavy for emerging technologies because they "lack cogent explanations of principles underlying the technology." It is difficult for the students to understand and apply the technology without such grounding into specific examples, cases and hands-on experiences. Another factor contributing to this need for grounding the content is the "movement between extreme levels of abstraction." Without examples and motivating cases, it is difficult to bridge this gap. The project experience also contributed to this grounding. As the students indicated (Item 14, Table 4), the projects were perceived as avenues to practice concepts and principles.

It is worth noting, though, that this impression was not a significant contributor to course satisfaction (see Tables 5 and 6). Nevertheless, lab sessions to facilitate demonstration and hands-on exposure, and the project to practice the principles were found valuable (Items 13 and 14, Table 4). As the semester progressed, the techniques for grounding the content evolved from examples (problem-solution pairs), to hands-on lab sessions (explorations of tools), and finally, to team projects (involving ill-structured situations). From learning syntax in an objective manner the focus shifted to construction of abstract concepts [O'Laughlin 1992] to a deeper, more elaborate processing where students assumed the role of apprentices [Brown et al 1989] as they learned about practical applications of this knowledge. Recommendations for grounding the course content, based on the above discussion, may be summarized as:

- multiple course elements should be deployed for grounding the course content, including use of examples and projects, and hands-on sessions to explore tools that implement the technology,
- the instructors should engineer this evolution with appropriate course elements (e.g. lab sessions) and practices (e.g. in-class discussions of cases and projects).

7.3 Facilitating evolution of instructor/ student roles

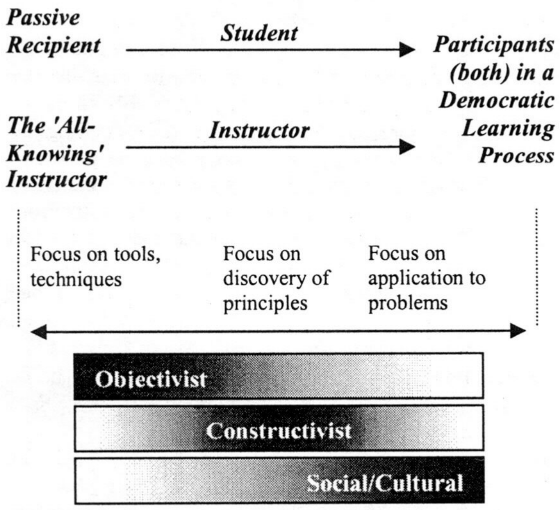
Roles refer to the responsibilities adopted by instructors and students through the semester. A consequence of the first two sets of recommendations is their impact on these roles. We suggest that the role of the instructor should evolve –

from that of an all-knowing instructor to a participant in the learning process. It is necessary to enlist cooperation from the students for this evolution. As the instructor begins to share control over the class content and conduct, the students should become willing collaborators. Such transitions are easier to achieve with more established technologies because of easier assimilation of the syntax, ready availability of principles, and available reports of application. For the XML course reported in this paper, the attempts to achieve this transition with the use of democratic instructional methods were a mixed success. Sometimes, they succeeded beyond expectations; at other times, the participation was lukewarm. Determining specific conditions of success for these remain an open question. We suspect that an explicit articulation of this need for evolution may, in fact, facilitate the transition of roles. The pedagogical dilemma, therefore, may resolve itself as an evolution of roles. Recommendations for the roles of students and instructor, based on the above discussion, may be summarized as:

- the roles should evolve during the course to accommodate shifting of tasks and responsibilities
- the instructor should facilitate this evolution by making the transitions explicit, for example, by transitioning from course elements such as lab sessions to others such as project discussions

7.4 Concluding remarks

The challenges of teaching emerging technologies are multi-faceted. In this paper, we have attempted to understand one of these challenges: the pedagogical dilemma that educators



Legend: Shaded portions in each box indicate suitability of approaches to goals. Idealized roles the Instructor and the student may play appear at the two extremes, in italics

Figure 3. Evolutions during a term

face when engaging students to learn emerging information technologies. One way to view this paper is a descriptive report on a first offering of a course for teaching emerging IT. In spite of the positive student feedback, the instructor reflections suggest that the course was only partially successful. The account we have presented can, therefore, be seen as a case description of a failure, which can lead to better approaches to teaching emerging information technologies. A second perspective would be to provide the readers a plausible approach for teaching emerging information technologies. In particular, the evolutionary stance to the epistemology of learning we have advocated has helped us to better understand and sharpen our own approaches to teaching. The recommendations we have outlined then present a rudimentary set of policies that provide a working theory for teaching emerging information technologies. These will, clearly, require further investigation to assess their effectiveness and applicability in different contexts and situations. The usual caveats of single case and individual reflections also apply to our analysis. The theory-based and data-driven discovery of recommendations we have presented, however, represent an effective starting point to improve our approaches to teaching emerging information technologies. As we aspire to become better educators and face increasing demands to keep up with emerging IT, we will need practices that can address these challenges. We hope that the present discussion has served as a starting point for doing so.

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10. ENDNOTES

1. The XSL specification, like several others, has, since that time, undergone a number of changes. For the current version, see the technical draft at http://www.w3.org/TR/xslt20/ dated 12 Nov 2003, accessed 20 February 2004.
2. For current versions of these standards, see http://www.w3.org/XML/ accessed 20 February 2004.
3. Deprecation means a feature is no longer considered important. It provides an indication to the developers that they should no longer use it (see http://java.sun.com/docs/books/tutorial/post1.0/converting/deprecation.html).
4. This capability has, since, been added to several commercial tools including market leaders such as Oracle (see description at http://technet.oracle.com/products/oracle9i/daily/jan23.html accessed 10 February 2004).
5. Neither was the sample size adequate for a confirmatory factor analysis. Reporting means and factor analysis for Likert scale items was acceptable because the intent was not to report inferential statistics to support or refute hypotheses.

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Appendix 1: Questionnaire used to obtain student feedback

	Content	Agree					Disagree
1.	I learned that managing documents is an advanced form of data management.	1	2	3	4	5	6
2.	I see the connection between this course and the basic Database course?	1	2	3	4	5	6
3.	The cource focused on tools and syntax at the expense of theory and principles.	1	2	3	4	5	6
4.	The course focused on theory and principles at the expense of tools and syntax.	1	2	3	4	5	6
5.	The course provided sufficient examples of the technologies covered.	1	2	3	4	5	6
6.	There was a mismatch between theory discussed in class and the tools available for using the theory.	1	2	3	4	5	6
7.	The new and evolving standards for XML technologies were difficult to understand and use.	1	2	3	4	5	6
8.	It was difficult to integrate the different technologies such as DTD, XML, XLL, XSL etc.	1	2	3	4	5	6
9.	I believe that this course using XML was of more value to me than a traditional advanced database course	1	2	3	4	5	6
10.	I believe that a traditional advanced database course would have been of more value to me	1	2	3	4	5	6
11.	The course provided sufficient guidelines about how to use the new technologies for solving problems.	1	2	3	4	5	6

	Methods	Agree					Disagree
12.	The course emphasized discussions during class instead of presentations from teachers.	1	2	3	4	5	6
13.	The hands-on lab sessions were helpful in understanding the concepts	1	2	3	4	5	6
14.	The projects provided sufficient opportunities to practice the concepts and principles discussed in class.	1	2	3	4	5	6
15.	The course emphasized group work at the expense of lectures.	1	2	3	4	5	6

(The questionnaire provided room for answering these questions.)

16. What will you consider as the main problems when teaching new technology as XML?
17. What do you feel you gained by learning XML in an advanced DB course?
18. What do you feel you lost by learning XML instead of traditional topics in an advanced DB course?
19. What were the worst things about this course this term?
20. What were the best things about this course this term?

21.	Overall, I am satisfied with the course.	1	2	3	4	5	6
22.	The College should have courses in the "technological front", and accept courses with less structure.	1	2	3	4	5	6
23.	The College should wait till a new technology is stable, and fully working as expected before offering courses.	1	2	3	4	5	6