

REUSE OF DIGITAL LEARNING RESOURCES  
IN COLLABORATIVE LEARNING ENVIRONMENTS

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# Abstract

With background in the proliferation of Information- and Communication Technologies (ICTs) in educational institutions, there is a growing interest in deploying ICT that complies with specifications and standards for learning technologies in these institutions. A key to obtaining the benefits of cost-efficiency and quality that motivate this interest is reuse of digital learning resources. Despite the significant efforts being made in design and deployment of learning technology standards facilitating the reuse of learning resources, the phenomenon of *reuse* is understudied.

Central standardization initiatives originate in the requirements for training in large corporations and the US military. My research is concerned with learning resource reuse in educational institutions, with a particular interest in pedagogical approaches emphasizing the social aspects of learning. The central aim of my research is to develop a conception of reuse that facilitates systematic analysis of learning resource reuse in ICT-mediated collaborative learning environments. This aim locates my research at the intersection between learning technology standardization and the research area of Computer Supported Collaborative Learning (CSCL).

The theoretical basis for my research is sociocultural perspectives on human learning and development. This perspective contends that the process of learning is essentially a social process, situated in cultural and historical contexts. The sociocultural understanding of technological agency, that human actions are mediated by artifacts, has fundamentally shaped my understanding of learning resource reuse. I have used the more specific approach of Cultural-Historical Activity Theory as my analytical framework, which implies that I have studied the students, teachers, and technology designers' engagement with learning resources as activity.

The empirical basis for the research is formed by three interpretive case studies. Two of the case studies were carried out on an introductory course on object-oriented programming at the University of Aarhus in Denmark, during two consecutive semesters. The third case study was conducted on the development of a framework for technology-enhanced inquiry learning at the University of California, Berkeley, USA.

The most important contribution of my research is that it brings the issue of how learning resources are reused in educational institutions into the foreground. The intermediate con-

cept of reuse developed in this thesis informs the two research areas CSCL and learning technology standardization. It serves as a mechanism for discussing the issue of scalability of CSCL systems, and provides empirically informed perspectives on reuse to the learning technology standardization community.

I argue that standardization will become more relevant for CSCL research as experimental CSCL systems are brought into educational institutions and help shape the everyday practice in these institutions. Learning technology standards represent an opportunity for the CSCL research community to reify findings on productive collaborative interactions, and to implement sustainable CSCL systems in educational institutions.

The conception of reuse can be used in deliberations on standards deployment in educational institutions. It can help guide decisions on which learning resources to design according to standards, and the findings on how the specifications SCORM and IMS Learning Design accommodate collaborative learning approaches can assist decision-makers in choosing appropriate mechanisms for facilitating reuse of learning resources. For the design of learning technology standards, the conception of reuse offers an opportunity to think about how well the standards reflect reuse practice. The findings on how learning resources are reused can also be used for redesigning standards with respect to reducing complexity.

In addition to the findings on reuse, my empirical research on social interactions in distributed CSCL settings has yielded new insights on the communicative conditions constituted by CSCL environments in the problem domain of university-level introductory object-oriented programming. My research pays particular attention to how the mediating ICTs shape these interactions, as well as taking other aspects of the learning situations into account.



# 1 Introduction

There is a growing interest in specifications and standards for learning technology in many educational institutions. This interest is following a development where Information- and Communication Technologies (ICTs) are increasingly becoming an everyday part of learning and teaching in these institutions. Standards-compliant learning resources carry the promise of both reducing the cost of development and deployment of learning technologies, and improving the quality of learning experiences. One key issue for obtaining these effects is to design digital learning content in a way that facilitates their reuse. The idea of “reuse” in this context is that learning resources can be created once and used numerous times. Instead of creating digital content for each new course from scratch, the content can be assembled from multiple existing sources.

Despite the significant efforts being made in design and deployment of learning technology standards that facilitate the reuse of learning resources, the phenomenon of *reuse* is not well understood. A central aim of the research reported in this thesis has been to develop a richer understanding of learning resource reuse. This aim has been approached by empirical studies of students and teachers’ engagement with learning resources in their actual practice. My explorative studies have been carried out as two case studies on a net-based introductory course on object-oriented programming at the University of Aarhus, Denmark. The two case studies were carried out on the same course in two consecutive semesters; labeled IOOP 03 and IOOP 04 in this thesis. My work has been part of Project Comprehensive Object-Oriented Learning (COOL). Project COOL was concerned with learning and teaching object-orientation (see Section 1.2), and has thus given direction for my choice of this as the problem domain for my studies of learning and teaching activities.

Another important aim of my research has been to explore the relationship between learning technology standards and pedagogical approaches emphasizing collaborative aspects of learning. This aim has been pursued by means of a case study on the development of a framework for technology-enhanced inquiry learning, called SAIL. This case study was conducted at the University of California, Berkeley, USA.

My work is positioned within the discipline of Information Systems research, which is concerned with the development, use, and impact of information systems in organizational settings. The theoretical basis for my research is formed by sociocultural perspectives on hu-

man learning and development, where learning is regarded as an essentially social process. My analytical framework is constituted by Cultural-Historical Activity Theory. This framework for multi-level analysis views artifacts such as ICT-mediated learning environments as integrated into human activity, and offers mechanisms for understanding how the various components of learning activities are interrelated. My studies are concerned with use of learning resources in ICT-mediated learning environments. Such environments are of central interest to the research field of Computer Supported Collaborative Learning (CSCL). My analyses are informed by CSCL research, especially from studies of social interactions in distributed learning situations.

One expected contribution of my conception of reuse is that it will inform CSCL research with respect to deployment of sustainable CSCL systems in educational institutions. A second expected contribution of my research to CSCL research is the provision of new insights on the communicative conditions of ICT-mediated learning environments, with a particular emphasis on the role of learning resources. Another important ambition of my explorative studies of reuse is to inform the field of learning technology standardization with respect to both development and deployment of standards and specifications.

The next section presents the research questions guiding my work, along with the rationale for these questions. Section 1.2 gives a brief presentation of Project COOL, and the last section in this chapter presents the organization of the remainder of the thesis.

## 1.1 Research focus

My research is motivated by the current interest in specifications and standards for learning technology in educational institutions. My main interest is not in the standardization process itself, i.e. how the standards and specifications are developed, nor is it in how standards are deployed in educational institutions. My primary interest is in understanding reuse of learning resources in learning situations. But I do contend that actual practices with regard to reuse both shape and are shaped by development and deployment of learning technology standards. This position reflects a fundamental understanding of the relation between design and use of technology as dialectical, which implies that how a technological artifact is used is not determined solely by the features of the artifact. The theoretical basis for this position is discussed in Chapter 2.

Learning technology standardization can be understood as the process of specifying standards for learning technology. When I use the term “standardization” in the context of learning resource reuse, I mean the process of (re)designing the resource according to a standard or specification<sup>1</sup>.

With regard to the background for my research, it is of interest to reflect on the more general issue of motives for introducing new technology in educational systems. Charles Crook (forthcoming) identifies three policy themes that he suggests have acted to shape the design of new educational technologies in the UK. These are labeled *audit*, the concern that the educational institution should be able to account for their activities; *inclusion*, the concern to enlarge the constituency of higher education by extending opportunities for participation; and *autonomy*, the desire to give learners greater control over their study. The presentation of learning technology standards in Section 3.1 shows that these respond well to such political priorities, playing into auditing (in concert with Learning Management Systems), and facilitating for more cost-effective, individualized, and widely available training. Thus, from a policy perspective, the introduction of learning technologies that comply with standards might seem to be a viable direction for development of educational institutions.

The concept of classification serves as a further clarification of the motivation of my research. Bowker and Star (1996) argue that standardization usually presupposes classification: “every successful standard imposes a classification system” (Ibid, p. 15). Classification plays a significant role in the coordination of activities, and is thus a fundamental element in social life. According to Mäkitalo and Säljö (2002), classification – or categorization in their terminology – is basic to human life:

At the psychological level, categories serve as resources for perception, reasoning, and remembering in the many and varied situated practices in which people act. At the social level, categories are tools that enable people to collectively share perspectives, make sense of events and problems, and justify their actions (Hester & Eglin, 1997; Jayyusi, 1984). To categorize is a necessity in the coordination of human activities and in the production of social order. (Ibid, p. 160)

Naturally, not all classifications become standards. “Classifications may or may not become standardized. If they do not, they are ad hoc, limited to an individual or a local

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<sup>1</sup> The distinction between standards and specifications is discussed in Section 3.1.

community, and/or of limited duration.” (Bowker & Star, 1999, p. 15). An interesting question is what happens to the practices that are not captured in classification schemes represented in standards. Bowker and Star (Ibid.) argue convincingly about the risk of not seeing what is excluded – practices that are not represented run the risk of being made invisible.

At the outset of the present research project, the specifications and standards collected in the Sharable Content Object Resource Model (SCORM) represented the dominant approach to learning technology standardization. This framework has its origins in the needs related to technical training in large US corporations (primarily the aviation industry) and the US Department of Defense. My concern was that educational practices not represented in the SCORM framework could be in danger of being made invisible to policy makers, which in turn might erode these practices. The issue here is that SCORM might be adapted from the area of military and corporate training into educational institutions. In the context of CSCL practice, Wasson, Ludvigsen, and Hoppe (2003a) warn us that “the intrinsic features of ‘borrowed’ technologies might induce undesired types of learning in an unanticipated way. That is, the technology and artefacts used may come with a hidden agenda of which we are not fully aware.” (Ibid, p. xviii). In order to address this concern, I formulated the following research question, R-I:

**R-I:** *How do central learning technology standards and specifications accommodate pedagogical approaches found in educational institutions?*

Introduction of learning technology standards brings about changes in digital learning resources. That is, learning resources are transformed as a result of standardization. These resources are provided for the students in a context at the educational institutions in which they are used, often in some kind of ICT-based learning environment. Based on my theoretical position within sociocultural perspectives on human learning and development, I contend that use of learning resources in such environments are situated with respect to various interconnected aspects of the learning situations. These aspects include organizational, pedagogical, and technological components of the learning situation. They mutually constitute each other, which means that a transformation of learning resources used in a learning situation might affect other components of the situation. Therefore, an understanding of the role of the learning resources as a part of a larger whole is of importance for the deployment of learning technology standards. This concern is addressed by the second research question:

**R-II:** *What are the roles of digital learning resources in ICT-mediated learning environments?*

The issue of cost efficiency is central for learning technology standards deployment. Two key contributors to SCORM state that the driving force behind large-scale sharing and reuse of multimedia content components “stems from the notion that repurposing of such components can lead to important savings in time and money, and can enhance the quality of digital learning experiences” (Duval & Hodgins, 2004, p. 72). In the SCORM specification, it is stated that “Up-front investment is required to develop and convert learning content for technology-based presentation. These investment costs may be reduced by an estimated 50-80 percent through the use of learning content that is accessible, interoperable, durable and reusable.” (ADL, 2004d, p. 1-22). During the last three years, the IMS Learning Design specification has gained momentum, and is currently subject to substantial attention. The issue of cost reduction is also part of the motivation for this specification: A formal notation for course design “would increase the effectiveness of education and training and reduce the overall cost by making it possible to automate the laborious, repetitive parts of the process” (Koper, 2005, p. 4). Reuse of learning resources is central in obtaining the goals of cost reduction, and is therefore a core issue in the motivation for the standards and specifications. During the course of the present research, it became clear that the phenomenon is not well studied and understood. In other words, the problem addressed by standardization initiatives is not clear. This insight led to the formulation of the third research question, supplementing the two other questions:

**R-III:** *How are learning resources reused in educational institutions, and what kinds of resources are reused?*

The latter part of this question addresses practical deployment of standards. Are there some resources that are more likely to be reused than others? Design and development of resources in accordance with standards entails extra work. Therefore, it might be beneficial to direct the extra efforts at resources with the best potential for reuse.

My research is founded on an understanding of human activity as situated. Situated actions are actions taken in the context of particular, concrete circumstances (Suchman, 1987, p. viii). These circumstances refer to more than the physical context in which the activity takes place, activity “has its origins in our life-long involvement in a social and physical world that we share with other people and that is imbued with cultural meaning.” (Stahl, 2003, p. 529). This view gives priority to empirical studies of people engaged in practice.

My research does not aspire to answer these three broad and open-ended research questions in full, but rather to address them through studies of specific learning situations. The findings from these studies help form a better understanding of the issues addressed by the three questions, which together contribute to the aims of my research.

## 1.2 Project COOL

The project Comprehensive Object-Oriented Learning (COOL) started in October 2002 and concluded at the end of 2005. The main partners were InterMedia and the Department of Informatics, both at the University of Oslo, the Norwegian Computing Center, and Simula Research Laboratory. The project was initiated by one of the inventors of object-oriented programming, Kristen Nygaard<sup>2</sup>.

During the last decade, object-orientation has become a common mode of teaching introductory computer science. With a basis in the modeling school of object-orientation (Madsen, Møller-Pedersen, & Nygaard, 1993; Smørdal, 1998), Project COOL has been concerned with exploring challenges met in learning this philosophy and its corresponding concepts. The problem domain addressed by Project COOL is a central issue in the research field of Computer Science Education (CSE) (Fjuk, Holmboe, Jahreie, & Bennedsen, 2006). Holmboe (2005) has identified three main strands of research informing the field of CSE. The major contributions to CSE come from cognitive psychology, CSE practitioner reports, and the fields of Human Computer Interaction and Computer Supported Collaborative Learning. Research in the field of CSE, especially in the cognitive psychology strand, has traditionally focused on programming language constructs and their comprehensibility. During the late 1980s and 1990s, the interest of the field shifted more towards comparative studies of different notational systems or programming paradigms. More recently, the study of students' comprehension of object-oriented concepts as such has become more central (Karahasanovic & Holmboe, 2006). Following this recent trend, Project COOL has explored the challenges of learning object-orientation by studying relationships between tools and programming environments, types of learners, pedagogical approaches and learning strategies, learning resources, and ICTs. The research has been carried out by conducting a number of case studies, design experiments, and controlled experiments (Fjuk, Karahasanovic, & Kaasbøll, 2006). This approach to the problem domain locates Project

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<sup>2</sup> Kristen Nygaard passed away just a few months before the start of the project. A memorial site is located at [http://www.ifi.uio.no/in\\_memoriam\\_kristen/](http://www.ifi.uio.no/in_memoriam_kristen/)

COOL in the strand of CSE research informed by Computer Supported Collaborative Learning.

As part of Project COOL, a major part of my empirical research has been carried out in the domain of learning and teaching object-oriented programming. Even though I consider the characteristics of this knowledge domain to be important for understanding the learning situations I have studied, my work has not been explicitly informed by the research agendas in the field of CSE. The central research object in my studies has been reuse of learning resources, and my contribution to Project COOL is concerned with artifacts used in learning object-orientation. However, my research is founded on an understanding that learning is situated (see Section 1.1). One aspect of the situated context is constituted by the characteristics of the knowledge domain. Therefore, some of the findings resulting from my research could be more readily applicable in the domain of introductory object-oriented programming than other domains.

Findings from the project are collected in the anthology *Comprehensive Object-Oriented Learning: The Learner's Perspective* (Fjuk, Karahasanovic, & Kaasbøll, 2006). As part of my work in Project COOL, I have also co-authored the following papers that are not included in the thesis:

- Berge, O., Fjuk, A., Groven, A. K., Hegna, H. and Kaasbøll, J. (2003). Comprehensive Object-Oriented Learning – an Introduction. In *Journal of Computer Science Education* **13** (4), pp. 331-335.
- Kaasbøll, J., Berge, O., Borge, R. E., Fjuk, A., Holmboe, C. and Samuelsen, T. (2004). Learning Object-Oriented Programming. In E. Dunican and T. Green (Eds.), *Proceedings of the 16th Annual Workshop of the Psychology of Programming Interest Group*, pp. 86-96. Carlow, Ireland: Institute of Technology.
- Berge, O., and Fjuk, A. (2005). Att förstå lärgemenskapers komplexa organisationsformer. In O. Jobring and U. Carlén (Eds.), *Att förstå lärgemenskaper och mötesplatser på nätet*, pp. 55-79. Lund, Sweden: Studentlitteratur.
- Fjuk, A., & Berge, O. (2005). Learning the process of programming through ICT-mediated apprenticeship. In L. Dirckinck-Holmfeld, B. Lindström, B. M. Svendsen and M. Ponti (Eds.), *Conditions for productive learning in networked learning environments* (pp. 37-47). Aalborg, Denmark: Kaleidoscope, Aalborg University.

## 1.3 Organization of the thesis

This thesis consists of an introductory essay (Chapters 1 through 7) and five research papers, provided as appendixes. In this section, an overview of the introductory part is presented followed by a list of the five research papers. This section is concluded by a table presenting an overview of which papers address which research questions and the empirical material they are based on.

The theoretical basis for my research is presented in Chapter 2. This basis is constituted by sociocultural perspectives on human learning and development, which implies a view that the process of learning is essentially a social process. Moreover, the sociocultural concept of artifact mediation as an account for technological agency in human activity is explained, a concept that has fundamentally shaped my understanding of learning resources. Chapter 2 also provides a description of my analytical framework, Cultural-Historical Activity Theory. Adopting this framework in my analyses means that I have studied the students, teachers, and technology designers' engagement with learning resources as activity.

Research related to my work is presented in Chapter 3, which clarifies my research position with respect to the two areas of interest, learning technology standardization and Computer Supported Collaborative Learning. I describe the concept of learning objects, which is a central construct in work on learning technology standardization, and discuss the relationship between object-oriented programming and learning objects. Then I present the two central specifications SCORM and IMS Learning Design, and discuss these with respect to reuse. Turning to CSCL, I first present the field in broad terms before focusing on the research that has informed my studies and analyses more directly. Chapter 3 is concluded with a discussion on how the research field of CSCL has approached standardization issues.

The research method is presented and discussed in Chapter 4. In this chapter, I give an account of the research design and its rationale, an overview of how the data analyses have been carried out, and a discussion of the trustworthiness of my research in terms of reliability, validity, and generalizability. The empirical part of the work is constituted by a pilot study conducted at the University of Oslo, two case studies at the University of Aarhus in Denmark (IOOP 03 and IOOP 04), and a case study at the University of California at Berkeley, USA (SAIL).



A summary of the research findings is provided in Chapter 5. In the first part of this chapter, the presentation of the findings is structured according to the research questions they address. Following this, the implications of my research for the two research areas presented in Chapter 3, learning technology standardization and Computer Supported Collaborative Learning, are discussed.

The introductory part of this thesis ends with Chapter 6, which contains conclusions and suggestions for further research.

The five research papers included as appendixes are:

**Paper I:** Berge, O. and Slotta, J. (*forthcoming*). Learning Technology Standards and Inquiry-Based Learning. Accepted for publication in K. Harman & A. Koohang (Eds.), *Learning Objects: Standards, Metadata, Repositories, & LCMS*. Santa Rosa, CA: Informing Science Press.

**Paper II:** Fjuk, A., Berge, O., Bennedsen, J. and Caspersen, M. (2004). Learning Object-Oriented Orientation through ICT-mediated Apprenticeship. Published in Kinshuk, Looi, C., Sutinen, E., Sampson, D., Aedo, I., Uden, L., Käköen, E. (Eds.) *Proceedings of the 4th IEEE International Conference on Advanced Learning Technologies* (pp. 380-384). Los Alamitos, CA: IEEE Computer Society.

**Paper III:** Bennedsen, J., Berge, O. and Fjuk, A. (2005). Examining social interaction patterns for online apprenticeship learning – Object-oriented programming as the knowledge domain. Published in the *European Journal of Open, Distance and E-learning*, 2005 / II.

**Paper IV:** Berge, O. and Fjuk, A. (2006). Understanding the Roles of Online Meetings in a Net-Based Course. Published in the *Journal of Computer Assisted Learning*, 22 (1), pp. 13-23.

**Paper V:** Berge, O. and Fjuk, A. (2006). Reuse of Learning Resources in Object-Oriented Learning. Published in A. Fjuk, A. Karahasanović and J. Kaasbøll (Eds.) *Comprehensive Object-Oriented Learning: The Learner's Perspective* (pp. 131-155). Santa Rosa, CA: Informing Science Press.

The table below gives an overview of which research questions these papers address, and the empirical basis for them.

	R-I	R-II	R-III
Paper I	SAIL		
Paper II		IOOP 03	
Paper III		IOOP 03	
Paper IV		IOOP 03	
Paper V			IOOP 03 IOOP 04

Table 1: Contribution of the research papers to the research questions

## 2 Theoretical Basis

My background is in the discipline of Information Systems (IS) research. This discipline is concerned with the development, use, and impact of IS in organizational settings (Myers & Avison, 2002). IS research focuses more on interactions between people, organizations and technology rather than on the technologies themselves, and as a discipline it is essentially an applied social science pertaining to the use and impact of technology (Elliot & Avison, 2005). IS researchers draw on a wide body of theories. The theoretical basis for my research is in sociocultural perspectives on human development and learning. I present central issues in sociocultural theory in this chapter, as well as the more specific analytical framework of cultural-historical activity theory.

### 2.1 Sociocultural perspectives

The task of sociocultural analysis is to “explicate the relationships between human *action*, on the one hand, and the cultural, institutional, and historical contexts in which this action occurs, on the other.” (Wertsch, 1998, p. 24). This implies a view that human action is situated with respect to cultural, institutional, and historical contexts. A fundamental tenet in sociocultural theory is that learning is a social process:

Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first, *between* people (*interpsychological*), and then *inside* the child (*intrapsychological*). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relations between human individuals. (Vygotsky, 1978, p. 57)

Vygotsky makes it clear that learning is not only influenced by social interactions between people, learning *is* fundamentally social in nature. An implication of this view is a shift away from studying learning as something that only happens within the individual: “We should not seek the origins of abstract thinking and categorical behavior (...) within human consciousness or within the human brain. Rather, we should seek these origins in the social forms of human historical existence.” (Luria, 1981, p. 27). As indicated by Luria, sociocultural theory is concerned with historical-cultural development with respect to learning. In his work on the relation between thought and language, Vygotsky sees mastery of verbal

thought as a prerequisite for learning: “The child’s intellectual growth is contingent on his mastering the social means of thought, that is, language.” (Vygotsky, 1986, p. 94). He proceeds to emphasize the role of historical-cultural development in learning:

Verbal thought is not an innate, natural form of behavior, but it is determined by a historical-cultural process and has specific properties and laws that cannot be found in natural forms of thought and speech. Once we acknowledge the historical character of verbal thought, we must consider it subject to all the premises of historical materialism, which are valid for any historical phenomenon in human society. (Vygotsky, 1986, pp. 94-95).

We have established that in a sociocultural perspective, learning is regarded as a fundamentally social process, subject to historical-cultural development. Further, culturally developed knowledge is embodied in artifacts (discussed below). In line with this, sociocultural theory understands knowledge as distributed among people and their environments, including objects in the environment and the communities they are a part of (Greeno, Collins, & Resnick, 1996).

Vygotsky (1978) describes how activity – human beings’ interaction with each other and the world – is fundamentally mediated by artifacts. This concept of mediated activity is fundamental in sociocultural theory on human development. Mediational means shape human actions in essential ways (Wertsch, 1991), but they should not be viewed as determining action in some kind of static, mechanistic way (Wertsch, 1998). The subject interacts with the objects in its environment by the help of artifacts, where the object serves a purpose for the subject. If the purpose of an action is to change some property of the external world, one typically employs tools to achieve the desired objective. One example of a tool is the *Enterprise Architect* software package. I can use this tool for creating and modifying UML<sup>3</sup> models of a new computer system. The tool extends my capabilities for creating a complex model by, for example, providing support for tracking dependencies in my model. Analogously to how tools are used as an auxiliary means for changing the world around us, signs are used as an auxiliary means for solving a given psychological problem, such as remembering, comparing, etc. But, in contrast to tools, signs are means for internal, men-

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<sup>3</sup> The Unified Modeling Language (UML) is an object modeling and specification language that can be used to specify, visualize, and document models of software systems.

tal, activity – they are internally oriented. A design pattern<sup>4</sup> is an example of a sign, or intellectual artifact. If I encountered the problem of notifying several objects of any changes in the state of one of the objects in my design, I could use my knowledge of the *Observer* design pattern to help me model this behavior. The design pattern is a generalized construct which can guide me in the modeling for my particular purpose.

Mediated action is bi-directional. Humans shape mediational artifacts, and the artifacts shape human actions. This means that I would go about creating an UML model in a different way if I were to use the drawing tool Microsoft Visio instead of the Enterprise Architect. Artifacts possess the specific function of reverse action (Vygotsky, 1978).

Understanding artifacts as tools or signs can be a useful analytical aid, but Engeström points out the dynamic nature of this relation:

The mediating artifacts include tools and signs, both external implements and internal representations such as mental models. It is not particularly useful to categorize mediating artifacts into external or practical ones, on the one hand, and internal or cognitive ones, on the other hand. These functions and uses are in constant flux and transformation as the activity unfolds. An internal representation becomes externalized through speech, gesture, writing, manipulation of the material environment – and vice versa, external processes become internalized. Freezing or splitting these processes is a poor basis for understanding different artifacts. Instead, we need to differentiate between the processes themselves, between different ways of using artifacts. (Engeström, 1999b, p. 381)

My research is concerned with learning resources, which I regard as artifacts. When discussing reuse of learning resources, one usually refers to reuse of physical artifacts. But when studying the creation, use, and reuse of these physical artifacts, the interrelation between physical and intellectual artifacts becomes relevant. Intellectual artifacts can become physical learning resources through externalization, and learning resources can help shape, for example, students' internal representation through internalization.

Artifacts mediate human activity. Intellectual as well as physical artifacts are evidence of the humans' ability to collect experiences and employ them for their purposes (Säljö, 2001). Artifacts embody accumulated human experience and knowledge; they are manifestations of culturally developed insights:

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<sup>4</sup> In the context of software engineering, a design pattern is a template for how to solve a problem in software design that can be used in many different situations

Artifacts carry with them successful adaptations of an earlier time (in the life of the individual who made them or in earlier generations) and, in this sense, combine the ideal and the material, such that in coming to adopt the artifacts provided by their culture, human beings simultaneously adopt the symbolic resources they embody. (Cole, 1999, p. 90)

Artifact mediation, then, is a way of transmitting cultural knowledge. “Tools and culturally developed ways of using tools shape the external activity of individuals.” (Kaptelinin, 1996b, p. 53). This perspective implies that artifacts inherently embody knowledge; this is an intrinsic feature of artifacts. Following from this, resources for learning are not limited to artifacts that are explicitly created for learning. Artifacts originally created for other purposes, as well as ways of using these, are part of the resources that can be drawn upon in learning processes.

In a sociocultural perspective, analyses of learning entail a special interest in communicative processes. Individual learning and social interactions are different aspects of the same phenomenon – “intra-individual and inter-individual functions mutually constitute each other. In other words, not only does collaboration between the learner and other people change some preexisting individual phenomenon, but it also directs and shapes both the general orientation and specific content of individual development.” (Kaptelinin & Cole, 2002, pp. 303-304). A concern with artifacts is another implication for analysis in a sociocultural perspective. Learning and development involves mastery of intellectual and practical artifacts – signs and tools (Säljö, 2001). Human cognition does not exist solely “inside” a person’s head, and it is not a solitary mental activity (Hutchins, 1995; Salomon, 1996). “Knowledge and learning will be found distributed throughout the complex structure of persons-acting-in-setting. They cannot be pinned down to the head of the individual or to assigned tasks or to external tasks or to the environment, but lie in the relations among them.” (Lave, 1996, p. 9). The persons-acting-in-setting structure includes cultural, institutional, and historical contexts (Wertsch, 1998).

I have emphasized the sociocultural view of knowledge and learning in this chapter. The reason for this is that, even though my research questions are not directed at learning *per se*, I study how learning resources are used in educational practice. These aspects of sociocultural theory form the basis for how I approach and conceptualize the use of learning resources by students and teachers.

My understanding of the term “learning resources” is also shaped by this theoretical basis. Learning resources are artifacts mediating students’ learning activities, including both intellectual and physical artifacts. This view implies that it is the *use* of the artifact that determines if it should be regarded as a learning resource, not the intention of the creators of the artifact. This conceptualization of learning resources also means that the term includes more than traditional learning materials such as textbooks, multimedia presentations, and textual examples and exercises. Tools used in learning activities, such a paper and pencils, word processors, video conferencing software, Instant Messaging applications, and handheld computers can be learning resources.

In summary, sociocultural studies of learning involve analyses of artifact-mediated activity, situated in cultural and historical contexts, with emphasis on communicative processes. Using cultural-historical activity theory as my analytical framework, I have studied students and teachers’ engagement with learning resources as activity. This analytical framework is presented in the following section.

## 2.2 Cultural-Historical Activity Theory

Cultural-Historical Activity Theory has its historical origins in classical German philosophy, in the works of Marx and Engels, and in the Soviet Russian cultural-historical psychology of Vygotsky, Leontiev, and Luria (Engeström, 1999a). Activity theory is a descriptive tool rather than a strongly predictive theory (Nardi, 1996a). “Broadly defined, activity theory is a philosophical and cross-disciplinary framework for studying different forms of human practices and development processes, with both individual and social levels interlinked at the same time.” (Kuutti, 1996, p. 25). It is used in areas such as cultural psychology (Cole, 1999), developmental work research (Engeström, 2005a, 2005b), and within various disciplines of Information Systems research, such as Computer Supported Collaborative Work (Bardram, 1997; Kuutti, 1991), Computer Supported Collaborative Learning (Fjuk & Ludvigsen, 2001; Gay, Rieger, & Bennington, 2002), Human Computer Interaction (Bødker, 1989; Nardi, 1996b), and the more general field of systems development (Bertelsen & Bødker, 2000; Smørdal, 1998).

Activity is the basic unit of analysis in activity theory, regarded as the minimal meaningful context for understanding individual actions (Kuutti, 1996). The analytical understanding of activity in activity theory is founded on Leontiev’s concept:

Thus in the total flow of activity that forms human life, in its higher manifestations mediated by psychic reflection, analysis isolates separate (specific) activities in the first place according to the criterion of motives that elicit them. Then actions are isolated — processes that are subordinated to conscious goals, finally, operations that directly depend on the conditions of attaining concrete goals. (Leontiev, 1978, pp. 66-67).

Activities are analytically isolated by the motive that elicits them, and they are directed towards an object. The object of activity is one of the most basic concepts of activity theory, and it can be regarded as “the sense-maker” (Kaptelinin, 2005). “An activity is a form of doing directed to an object, and activities are distinguished from each other according to their objects. Transforming the object into an outcome motivates the existence of an activity” (Kuutti, 1996, p. 27). In Leontiev’s three-tiered structure of activity, a motive-driven activity is realized through goal-oriented, conscious actions. One action might help realize various activities, and one motive might find expression in several actions. Actions are carried out by operations, under given conditions typically not consciously reflected upon by the one carrying them out. This structure is dynamic in the sense that processes can move between the levels. For example, when a student becomes skilled in using a computer keyboard, entering text will move from being a conscious action to become an operation that does not require much conscious attention.

Activity theory has been developed as a psychological approach, dealing almost exclusively with individuals (Kaptelinin, 1996b). The cultural-historical tradition of activity theory (CHAT) emphasizes the social nature of human beings and their activities, and Engeström’s activity system is one attempt to expand the concept of activity to supra-individual phenomena (Ibid.). An activity system models a object-oriented<sup>5</sup>, collective, and culturally mediated human activity (Engeström & Miettinen, 1999). In this systemic model of activity, proposed by Engeström (1987), the subject’s actions towards the object of the activity is mediated by both instruments (artifacts) and the people who share the same object – the community. The subject’s relation to the community is mediated by rules, and the relation between the community and the object is mediated by division of labor. This model is shown in Figure 1.

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<sup>5</sup> The term “object-oriented” in the context of CHAT means that analytically, human activity is directed towards an object. It is homonymous with the term as it is understood in object-oriented programming, where the term refers to mapping between ‘real-world phenomena’ and a computer system model or program.



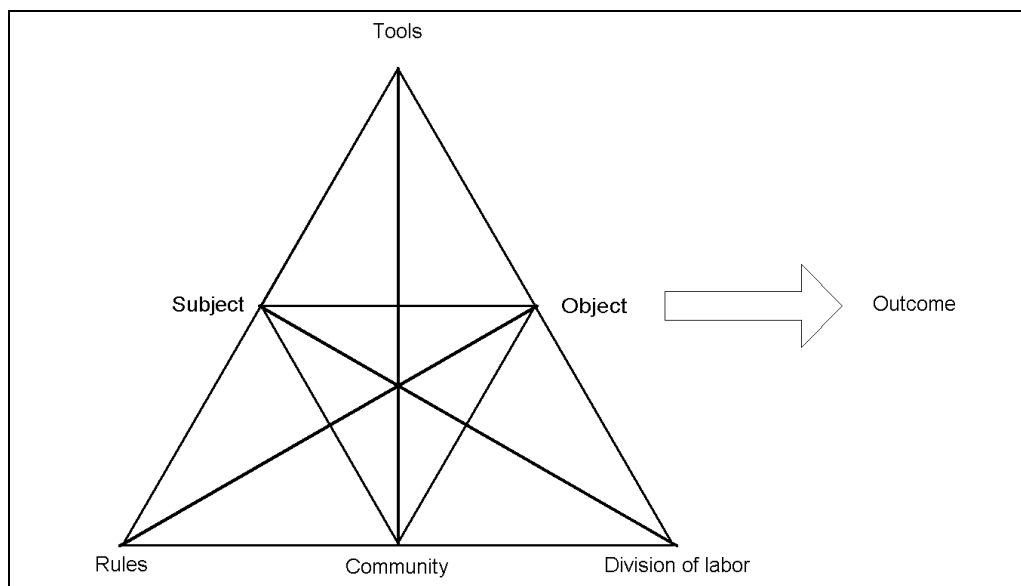


Figure 1: Engeström's activity system<sup>6</sup>

The concept of contradictions is a powerful analytical instrument in activity theory, and they are the engine of change and development as well as a source of conflict and stress (Cole, Engeström, & Vasquez, 1997). Contradictions are not the same as conflicts; they are historically accumulating structural tensions (Engeström, 2001). “Activity theory sees contradictions as sources of development; activities are virtually always in the process of working through contradictions.” (Kuutti, 1996, p. 34). Contradictions are inevitable features of activity, and “new qualitative stages and forms of activity emerge as solutions to the contradictions of the preceding stage of form.” (Engeström, 1987, p. 91). A fundamental contradiction within the structure of productive activity is the discrepancy between individuals’ goals and actions and the total activity system (Ibid.). “Such contradictions can result in a revision of individual values, goals, and strategies and, consequently, in creating new forms of joint activity.” (Kaptelinin & Cole, 2002, p. 306).

Engeström (1987) describes four levels of contradictions, illustrated in Figure 2 on page 19. Primary contradictions are found within each constituent component of the central activity, within each corner of the triangle of activity. One example of a primary contradiction in the tool component can be features of a specific constellation of artifacts. Videoconferencing software can be used to emulate co-located meetings in a distributed net-based course on data structures. But if some participants’ internet connections have insuffi-

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<sup>6</sup> The figure is reproduced from (Engeström, 1990)

cient bandwidth, the video transmission might be disrupted and make it difficult for them to participate in the discussions. This would constitute a contradiction between the intention of using the technology and the affordances of the video-conferencing software combined with the bandwidth of the participants' internet connections.

Secondary contradictions are those appearing between the constituents of the central activity. An example of a secondary contradiction can be between the rules and the tools components. The pedagogical approach in the course on data structures can be one emphasizing small-group collaborative problem solving, where one seeks equal opportunities for participation and communication within the group. The video conferencing system, however, is designed to support large business meetings with one meeting leader. Only the meeting leader can present documents in the shared workspace of the application, and the other participants need the permission of the meeting leader to voice their opinion. Such a set-up might represent a contradiction between the tools component of the activity (the video conferencing software) and the rules component (the pedagogical approach).

Tertiary contradictions are located between the object/motive of the dominant form of the central activity and the object/motive of a culturally more advanced form of the central activity, introduced by representatives of culture. One example of a tertiary contradiction can be between the ambition of students and the teachers with a particular task. The students can be focused on solving a programming task given by the teacher with as little effort as possible. The object of the activity for the students is the programming task itself. The teacher is also engaged in enabling the students to make program code that is easy to maintain. She therefore encourages the students to produce code with low coupling between modules and to document their program code. Such an approach usually implies that more effort (in the short term) is required to produce the program code. The contradiction here lies in the tension between solving the task as quickly as possible and producing code of higher quality with long-term benefits.

Quaternary contradictions appear between the central activity and its neighbor activities. These neighbor activities are all the activities where the immediately appearing objects and outcomes of the central activity are embedded (object-activities), activities that produce key instruments for the central activity (instrument-producing activities), activities like education and schooling of the subjects of the central activity (subject-producing activities), and activities like administration and legislation (rule-producing activities). An example of a quaternary contradiction can be one found between the central activity and an

instrument-producing activity. For example, one can attempt to resolve the contradiction used above as an example of a primary contradiction by finding an alternative tool for emulating co-located meetings. In this instrument-producing activity, one might look for a new video conferencing software with better compression algorithms and thus lower bandwidth requirements. Perhaps this is a commercial software package with high licensing cost. The added expense introduced with the new software is not covered by the institution offering the course, and the students need to purchase the software in order to take part in the course. This, however, is at odds with the educational institution's policy of providing low-cost educational programs for continuing education, a program which our net-based course on data structures is a part. This is an instance of a quaternary contradiction between the instrument-producing activity and the central activity.

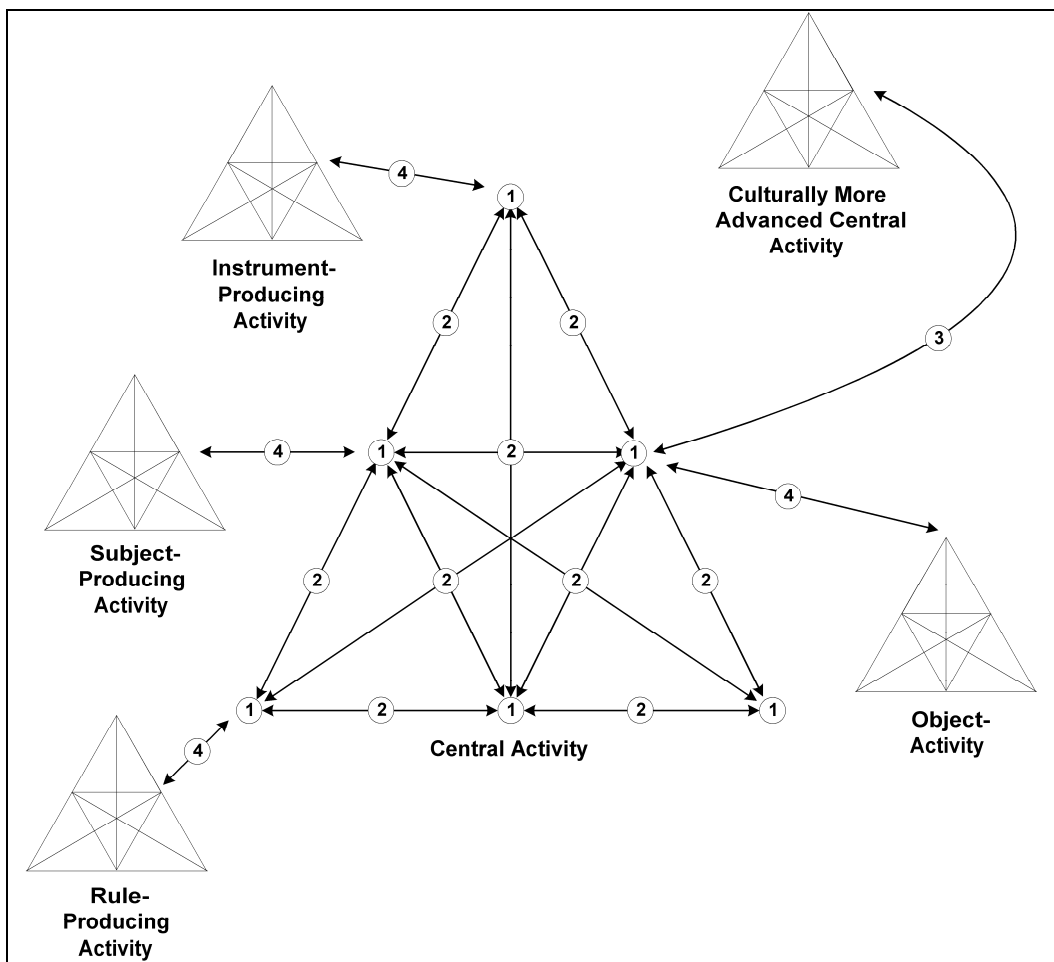


Figure 2: The four levels of contradictions<sup>7</sup>

<sup>7</sup> The figure is reproduced from the Center for Activity Theory and Developmental Work Research web site: <http://www.edu.helsinki.fi/activity/pages/chatanddwr/activitysystem/>

My approach to analysis of my empirical material has been grounded in contradictions, or areas of tension. Contradictions manifest themselves as problems, ruptures, breakdowns, and clashes within the system itself or in relation to other systems (Kuutti 1996). Using *the activity* as my unit of analysis (Fjuk & Ludvigsen, 2001), the analyses has been guided by contradictions identified in the activity systems I have studied. I have used contradictions as a point of departure for identifying potential improvements or developments of distributed CSCL systems, in the IOOP case studies (described in Chapter 4). Development “can be understood by tracing disruptions, troubles and innovations at the level of concrete modes of the activity, both historical and current.” (Engeström, 1996, p. 72). I have also used this approach in analysis of the SAIL case study material (see Chapter 4), for identifying tensions between learning technology standards and the designers’ aims with respect to technology-enhanced inquiry learning.

A more thorough discussion of how I have used CHAT in my analyses is provided in Section 4.2. In the following, I discuss the selection of CHAT as my analytical framework with respect to alternative approaches.

### 2.2.1 Discussion of the analytical framework

In a commentary on Information Systems research, Orlikowski and Iacono (2001) conclude:

Our commentary has been motivated by a belief that the tendency to take IT artifacts for granted in IS studies has limited our ability as researchers to understand many of their critical implications – both intended and unintended – for individuals, groups, organizations, and society. We believe that to understand these implications, we must theorize about the meanings, capabilities, and uses of IT artifacts, their multiple, emergent, and dynamic properties, as well as the recursive transformations occurring in the various social worlds in which they are embedded. (Orlikowski & Iacono, 2001, p. 133)

I contend that CHAT, which regards artifacts as mediating instruments for situated human actions, responds well to requirements of an analytical framework for studies addressing Orlikowski and Iacono’s call for theorizing the IT artifact. Two important reasons for me to select CHAT as my analytical framework were its view that activity needs to be studied in its context, and the understanding of knowledge as distributed among individuals and their environment. These perspectives are not unique to CHAT.

Two other approaches that share these fundamental perspectives are distributed cognition (Hutchins, 1995; Salomon, 1996) and actor-network theory (ANT) (Latour, 1987; Law, 1992). However, several activity theory researchers contend that there is an important ontological difference between these two approaches and CHAT. Both distributed cognition and ANT view artifacts and people as conceptually equivalent. People and artifacts are ‘agents’ or ‘actants’ in a system with both technical and non-technical elements – they are regarded as symmetrical nodes in a system (Engeström & Escalante, 1996; Miettinen, 1999; Nardi, 1996c, 2002). Through the concept of mediated action, CHAT contends an asymmetrical relationship between humans and artifacts where the intentionality and competence of people are taken into account (Kaptelinin, 1996a; Miettinen, 1999).

Hanseth (2005) argues that ANT researchers have developed a much richer notion of technological agency since the early 90-ies, and that the discussion on symmetry between humans and artifacts should be left behind. Hanseth’s argument is that it is not technology that acts, but a *hybrid collectif* of humans and technology. For example, walls only prevents the escape of prisoners while there are also prison guards (Law, 1992). This means that the difference between CHAT and ANT on technological agency might be more of an epistemological than ontological one.

One application area of ANT in IS research is standards and standardization processes (e.g. Hanseth & Monterio, 1997). However, it is not clear for me how ANT’s notion of technological agency can serve my purpose, which is the study of learning resource reuse. CHAT’s dialectical perspective on artifact mediation resonates with my understanding of the role of artifacts in human action, and I have found this explanatory status of artifacts well suited for my studies on learning environments and learning resource reuse.

CHAT is often used to study change in large corporations and public sector institutions, where research is carried out by actively initiating change in the settings under investigation (Rückriem & Lompscher, 2005). However, the current non-dogmatic nature of CHAT research affords various applications of the framework (Engeström & Miettinen, 1999). I have primarily used CHAT for analyzing non-intervention studies of relatively short duration (see Chapter 4). I have used CHAT for identifying problematic aspects of learning situations, insights which can be used for redesign, and for conducting a multi-level analysis of the roles of one particular artifact in a specific learning situation.

I have positioned my research with respect to the theoretical basis for my work in this chapter. In the next chapter, I position my work with respect to related research.



# 3 Related Research

This chapter provides an overview of the two research areas addressed in this thesis, and describes my position within these areas. As outlined in Chapter 1, my studies of learning resource reuse are founded on an interest in the introduction of learning technology standards and specifications in educational institutions. I present research in this area in the first section of this chapter, with particular emphasis on the two central specifications SCORM and IMS LD.

My focus on empirical studies where digital learning resources are used entails an interest in ICT-mediated learning situations. Moreover, with my basis in a sociocultural understanding of educational practice, situations where the social aspects of learning are emphasized are of special interest for me. This orientation locates my research in the field Computer Supported Collaborative Learning, presented in the second section of this chapter.

This chapter is concluded with a section discussing CSCL's involvement with learning technology standards, and possible directions for how the field can approach standardization.

## 3.1 Learning technology standardization

There are numerous initiatives working on open standards and specifications relating to educational technology. Central organizations include the IMS Global Learning Consortium<sup>8</sup> (IMS), Advanced Distributed Learning<sup>9</sup> (ADL), the IEEE Learning Technology Standards Committee<sup>10</sup> (IEEE LTSC), the ISO / IEC JTC1 sub-committee 36<sup>11</sup>, the ARIADNE foundation<sup>12</sup>, and the Aviation Industry CBT Committee<sup>13</sup> (AICC). These organizations work with issues such as learning content metadata, structuring and sequencing, learning designs, competency definitions and learning objectives, learner information,

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<sup>8</sup> <http://www.imsglobal.org/>

<sup>9</sup> <http://www.adlnet.org/>

<sup>10</sup> <http://ieeeltsc.org/>

<sup>11</sup> <http://jtc1sc36.org/>

<sup>12</sup> <http://www.ariadne-eu.org/>

<sup>13</sup> <http://www.aicc.org/>

e-portfolios, resource lists, accessibility, digital rights management, and content repository interoperability. My research is concerned with reuse of learning resources, and I therefore focus on standards and specifications for design and development of digital learning content.

Standards, in a strict sense, are produced by national or international standards bodies. Of the organizations mentioned above, only IEEE and ISO are standards bodies. The other organizations produce specifications for learning technology, which can be submitted to standards bodies. The Learning Object Metadata standard (Section 3.1.1) produced by IEEE has the status of standard in the strict understanding of the term. All other learning technology specifications I discuss in this thesis have the status of specifications. More informally, some specifications and formats can be generally accepted as *de facto* standards, for example the HTML specification produced by the World Wide Web Consortium or the .doc document format from Microsoft. Specifications can also become *de jure* standards. For example, the organization ADL has set SCORM (Section 3.1.3) as a *de jure* standard for the US Department of Defense (DoD); all suppliers of training materials to the US DoD must comply with this set of specifications (Olivier & Liber, 2003). For the sake of brevity, I sometimes use the informal meaning of standard when I discuss learning technology standards in this thesis.

A key concept in standardization of learning content is learning objects, described in the following section. Then the current discussion on how learning objects relate to object-oriented programming is addressed. Clarification of this issue is of interest here, since the subject domain of the learning situations studied in this thesis is object-orientation. Thereafter two central standardization initiatives are presented, the Shareable Content Object Reference Framework and IMS Learning Design.

### 3.1.1 Learning objects

Learning objects are educational resources that are modular units, which can be assembled to form larger constructs, such as lessons or courses (Wiley, 2000). The primary purpose of learning objects is to facilitate reuse, where the basic idea is that a learning content component can be part of various courses (Downes, 2004). Moreover, advocates of a standardized approach to design of learning objects often propose benefits with regard to the ability to use learning content with different Learning Management Systems, that it becomes more



robust with respect to changes in underlying infrastructure, easier to update, and more accessible (ADL, 2004d).

There is no commonly accepted definition of what constitutes a learning object. A very broad definition is given by IEEE in their standard for learning object metadata: “For this Standard, a learning object is defined as any entity – digital or non-digital – that may be used for learning, education or training” (IEEE, 2002). Another, much more specific, example is provided in a white paper from Cisco Systems: “Ideally, a learning object is based on a single learning or performance objective (...). Any learning object can be ‘tested’ through assessments that measure the learning or performance objective (...) everything found in the learning object is identified with metadata so that it can be referenced and searched both by authors and learners” (Cisco, 2003). Comprehensive overviews of various definitions are provided by McGreal (2004) and Koohang and Harman (forthcoming). A common criticism of IEEE’s definition is that it is so broad that it does not exclude anything (e.g. Wiley, 2000). On the other hand, very specific definitions such as Cisco’s might exclude entities that are obvious candidates for learning objects. The requirement that a learning object should include assessment might not be evident in problem-based learning, for example.

Learning objects can be exchanged through central repositories such as CAERO<sup>14</sup>, MERLOT<sup>15</sup>, and EducaNext<sup>16</sup>, or in peer-to-peer networks such as Edutella<sup>17</sup>. Sharing of learning resources raises the issue of resource discovery. Furnishing learning objects with metadata facilitates this. Metadata typically describes the content of the learning object in terms of the title, a textual description, keywords, location, technical format and requirements, pedagogical characteristics, type (exercise, simulation, narrative text, etc.), copyright information, etc. The most widely used standard for metadata specification is the IEEE 1484.12.1-2002 Standard for Learning Object Metadata (IEEE LOM). This standard is quite extensive (e.g., Friesen, Hesemeier, & Roberts, 2004), with 64 metadata elements. In a large survey on actual use of LOM elements, Friesen (2004a) reports that many elements were used only to a small extent. Due to the complexity of IEEE LOM, several application profiles have been developed. These contain a subset of elements from IEEE

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<sup>14</sup> <http://www.careo.org/>

<sup>15</sup> <http://www.merlot.org/>

<sup>16</sup> <http://www.educanext.org/>

<sup>17</sup> <http://edutella.jxta.org/>

LOM, and make their meaning in the context of the application profile explicit. Examples of IEEE application profiles are Canadian Core, CanCore (Friesen, Hesemeier, & Roberts, 2004), the SCORM Content Aggregation Model (ADL, 2004a), the Norwegian NORLOM (eStandard, 2005), and the Chinese E-Learning Technology Standard, CELTS (Xiang, Shen, Guo, & Shi, 2004).

Surveys of IEEE LOM usage (Friesen, 2004a; Friesen & Nirhamo, 2003) in learning objects and application profiles have shown that the metadata elements chosen frequently had equivalents in the Dublin Core specification. The Dublin Core metadata element set (DCMI, 2004) is a standard for cross-domain information resource description, and is not specifically developed for educational material. The Dublin Core element metadata set is smaller than IEEE LOM, with 15 descriptive semantic definitions. Other general approaches to semantic web solutions such as Topic Maps (ISO/IEC, 1999; Kennedy, 2000) and the Resource Description Framework (Klyne & Carroll, 2004) are currently being explored for use with learning material, for example by the EU project CALIBRATE<sup>18</sup>.

A learning object is made up of two components: Content and metadata describing the learning object. The content can be any element usually associated with multimedia content: text, graphics, Flash animations, sound, video clips, Java applets, or a combination of these. The question of the size of a learning object, or granularity, is central in the practical development of learning objects (Duncan, 2003; Wiley et al., 1999). The dilemma is that the smaller a resource is, the greater the possibility of it being reused in another educational context. However, larger resources usually have greater educational value. There is often a tension between increasing educational value and maximizing reusability (Littlejohn, 2003b). Also, there is the issue of providing metadata to learning objects: “Designating every individual graphic and paragraph of text within a curriculum a “learning object” can be prohibitively expensive. From an ‘efficiency’ point of view, the decision regarding learning object granularity can be viewed as a trade-off between the possible benefits of reuse and the expense of cataloging” (Wiley, 2000). There are various approaches to describing granularity; educational terms (course, module, unit), purpose terms (asset, reusable learning object), and size terms (number of pages, duration to complete) (Duncan, 2003).

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<sup>18</sup> [http://www.intermedia.uio.no/projects/research/calibrate\\_en.html](http://www.intermedia.uio.no/projects/research/calibrate_en.html)

One example of a learning object is the Heap Sort Visualization applet<sup>19</sup>. Heap sort is one of several sorting algorithms that are part of university-level computer science courses. The resource shown in Figure 3 simulates the execution of this algorithm. The sorting algorithm presented here takes a set of 15 numbers as input, and sorts these numbers in ascending order in an array. The Java source code is displayed on the right side, with a cursor (currently in line 6) that illustrates the stepwise execution of the code. The current state of the array of numbers is displayed at the bottom of the shaded area to the left. The tree structure above it is a representation of the temporary structure built by the algorithm for comparing and ordering the elements of the array. Color coding and animation is used to show which elements are compared and swapped.

Figure 3: The Heap Sort Visualization applet

For the purpose of illustration, I have created an IEEE LOM metadata description of this resource. For the sake of brevity, only the two elements “general” and “technical” are expanded in the XML code below.

```

1 <lom xmlns="http://ltsc.ieee.org/xsd/LOM">
2   <general>
3     <identifier>
4       <catalog>URI</catalog>
5       <entry>http://www.uio.no/~olaberge/LO/CS_110</entry>
6     </identifier>
7     <title>
8       <string language="en">Heap Sort Visualization</string>

```

<sup>19</sup> The Heap Sort Visualization is made by Mike Copely at the University of Hawaii, and is available at: <http://www2.hawaii.edu/~copley/665/HSApplet.html>

```

9  </title>
10 <language>en</language>
11 <description>
12   <string language="en">
13     The applet reveals the inner workings of the Heap
14     Sort sorting algorithm at an abstract level.
15   </string>
16 <keyword>
17   <string language="en">Heap sort</string>
18 </keyword>
19 <keyword>
20   <string language="en">Recursion</string>
21 </keyword>
22 <keyword>
23   <string language="en">Java loop structure</string>
24 </keyword>
25 <coverage>
26   <string language="en">Java</string>
27 </coverage>
28 <structure>
29   <source>LOMv1.0</source>
30   <value>atomic</value>
31 </structure>
32 <aggregationLevel>
33   <source>LOMv1.0</source>
34   <value>1</value>
35 </aggregationLevel>
36 </general>
37 <lifeCycle/>
38 <metaMetadata/>
39 <technical>
40   <format>text/html</format>
41   <format>image/gif</format>
42   <format>application/x-java-applet</format>
43   <size>35000</size>
44   <location>
45     http://www2.hawaii.edu/~copley/665/HSApplet.html
46   </location>
47   <requirement/>
48   <installationRemarks/>
49   <otherPlatformRequirements/>
50   <duration>
51     <duration>PT3M32S</duration>
52     <description>
53       <string language="en">
54         Minimum time to complete simulation is 3 min. 32 sec.
55       </string>
56     </description>
57   </duration>
58 </technical>
59 <educational/>
60 <rights/>
61 <relation/>
62 <annotation/>
63 <classification/>
64 </lom>

```

The applet, together with the metadata description, constitutes a learning object. I did not modify the applet itself when creating this learning object. It is only referenced, the loca-

tion being shown in line 45. The learning object can be placed in a repository, where it would be accessible for retrieval. One important function of the metadata is to facilitate discovery of the learning object. The title (line 8), the description (lines 13-14), and the keywords (lines 17, 20, and 23) are important mechanisms for this. A typical use of this learning object would be to supplement textbook material in undergraduate computer science courses on data structures and algorithm analysis. I estimate the work of creating the visualization applet to be at least a week for an experienced programmer. Reusing this learning object instead of creating it from scratch would therefore represent cost savings.

This example shows how the learning object can be reused in similar courses across educational institutions. But one can envision other types of reuse. For example, it can be used for visualizing the concept of recursion (a function calling itself), the execution of the Java *do* loop structure, or perhaps as an example of visualization of complex algorithms in a computer science education course.

### 3.1.2 Learning objects and object-oriented programming

Several scholars relate the concept of learning objects to object-oriented programming in the field of computer science. Both Wiley (2000) and Quinn & Hobbs (2000) claim that learning objects draw on object-oriented programming (OOP), and they both emphasize reuse as the important influence from OOP. Robson (1999) also relates learning objects to OOP, but the major concern here is objects understood as entities encapsulating data (properties of the object) and methods, and on relations between objects. Wiley states that “Object-orientation highly values the creation of components (called ‘objects’) that can be reused”, referring to an article on the programming language Simula I (Dahl & Nygaard, 1966). The two Norwegians Dahl and Nygaard are indeed widely recognized as the creators of object-oriented programming, which is today the predominant approach to software construction. The simulation language Simula I was followed by the general purpose programming language Simula 67 (Dahl, Myrhaug, & Nygaard, 1968), later renamed Simula. With Simula 67, the central object-oriented concept of classes and sub-classes (and thereby objects) was introduced. Software construction involves analysis, design, implementation, and evaluation, and object-orientation provides a framework that unifies these phases. A program execution is regarded as a physical model, simulating the behavior of either a real or imaginary part of the world (Madsen, Møller-Pedersen, & Nygaard, 1993, p. 16). Objects represent phenomena in the application domain (the world). Further,

an object is an instance of a class, or in other words, classes are abstract descriptions of objects of a particular kind (Barnes & Kölling, 2003). I agree with Wiley that reuse is perceived as a benefit of OOP, but it is not objects that are reused: “Contrary to frequent claims, objects are almost never sold, bought, or deployed. The unit of deployment is something rather more static, such as a class, or, more likely, a set or framework of classes, compiled and linked into some package.” (Szyperki, Gruntz, & Murer, 2002, p. 10).

The distinction between two approaches to object-orientation made by some researchers (e.g. Madsen, 1995; Smørdal, 1998) can help clarify the relation between OOP and learning objects. These two approaches are often referred to as the modeling (or Scandinavian) school and the reuse (or Smalltalk) school of object-oriented programming.

In the modeling school, objects and classes in the models represent phenomena and concepts in the real world; the emphasis is on computer programs as models of real-world phenomena (Nygaard & Dahl, 1981). The three main benefits of object-orientation are regarded to be real world apprehension, stability of design, and reusability (Madsen, Møller-Pedersen, & Nygaard, 1993). Reusability in this context is addressing the problem of incremental program modification. The functionality of an existing software component might be very similar to one needed in a new component. Instead of copying and modifying the code in the existing component, an approach with several drawbacks, the class/subclass construct in OOP can be applied. In this approach to object-orientation, reusability is closely related to how well the model reflects the real-world phenomenon. Learning object metadata is expressed in the eXtensible Markup Language (XML). This is a textual description language which takes an object-oriented view on information (Johnsen, 2001). XML resonates with the modeling school of OOP, in that the metadata elements describe “real-world” aspects of the learning object. This aspect of reuse is not much discussed in the literature on learning objects. Further, there is no notion of classes in learning objects. Thus, the relation between the modeling school of OOP and learning objects seems to be slim.

In the reuse school of object-oriented programming, the emphasis is on organization of software systems (Smørdal, 1997). Reuse is here understood in terms of modularization of program code. Program modules can be saved in a library and shared by several programs. An object-oriented approach provides strong mechanisms for this kind of reuse. This approach to reuse harmonizes well with the ‘classical’ view on learning objects, where they are explained with an analogy to Lego bricks (e.g. Hodgins & Conner, 2000). These are

units of various sizes and shapes, but with a standardized pin size. These bricks can be put together to form various structures. Similarly, learning objects can be put together in many ways to form various, larger units of learning content.

Attempts to use concepts from OOP for theorizing about learning objects are criticized by Sosteric and Hesemeier (2004), who state that “object-oriented theory should be discarded altogether when defining LOs [learning objects], and we should proceed to define LOs on their own terms.” (ibid., p. 37). It is clear that learning objects have little in common with objects in OOP, apart from the fact that they both facilitate reuse. It should be noted, however, that reuse in the modeling school of OOP is regarded as a side-effect of good abstractions, not as a goal in itself (Madsen, 1995). Implementation techniques that enhance the reusability of software include object-oriented concepts such as data encapsulation, information hiding, polymorphism<sup>20</sup>, abstract classes or methods, and inheritance (Ralston, Reilly, & Hemmendinger, 2000, p. 1642). With the exception of data encapsulation, these features are not represented in learning objects, and therefore there is probably little to gain from theories on object-orientation in the domain of learning objects.

Departing from a position where the term ‘object’ in learning object has clear origins in object-oriented programming, Friesen (2004b) finds the term ‘learning object’ problematic in itself. He claims that the term “juxtaposes two words that are in many ways incongruous and incommensurable. The first, ‘object’, is based thoroughly and very specifically on a technological paradigm (...). And the second, ‘learning’ is equally extreme in its vagueness, generality and broadly *non-technical* nature.” (Friesen, 2004b, p. 61). Even though the term ‘object’ might have its roots in OOP, it does also have an everyday meaning, as well as specific meanings in various fields. For example, CHAT (Section 2.2) is often described as an object-oriented, or object-related, framework (e.g. Kaptelinin, 2005). Actually, the concept of object in OOP is grounded in an everyday understanding of the term: “Object-oriented analysis is based upon concepts that we first learned in kindergarten: objects and attributes, wholes and parts, classes and members.” (Coad & Yourdon, 1991, p. 1). Due to the multiple meanings of the term ‘object’, it is not evident that it is associated with the term as understood in OOP. I therefore find Friesen’s objection to the term problematic.

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<sup>20</sup> Polymorphism is a mechanism that allows one function to have different behaviors, depending on the types it is applied to.

I have suggested that OOP theory is of little value for understanding learning objects. Another approach could be to draw on the experiences of reuse in the software industry, which could inform deployment of reusable learning resources. The visions of reuse benefits in this approach to OOP bear a striking resemblance to those in the learning object standardization communities:

Innovations such as object-oriented platforms – library-like repositories of stand-alone code fragments in reusable objects were touted as the solution to the reuse problem. The idea was that future developers would extract code from these “knowledge repositories” to efficiently retrieve existing solutions that match design problems. Coding a complex piece of software, in theory, would become much like putting together existing Lego blocks. (Desouza, Awazu, & Tiwana, 2006, p. 97)

However, the experience with software reuse so far has been mixed: “Two decades after the widespread commotion around reuse, its results in improving software quality, efficiency, and development agility have been dismal with no panacea in sight.” (Ibid.) Recently the software development industry has begun to shift away from reusing classes in program construction, towards Component-Based Development. Software components are “executable units of independent production, acquisition, and deployment that can be composed into a functioning system.” (Szyperski, Gruntz, & Murer, 2002, p. 3). Components in the form of, for example, Enterprise Java Beans or Microsoft COM components, are assembled to build computer systems. One feature that distinguishes components from classes with respect to reuse is that components have coarser grain size. (Mohagheghi, 2004) Components are higher level aggregates than classes. Service-oriented computing is another approach that facilitates reuse. In this case, the unit for reuse is services, which are “self-describing, open components that support rapid, low-cost composition of distributed applications.” (Papazoglou & Georgakopoulos, 2003, p. 26). Services are offered by service providers, often external to the organization that develops the application in which the service is used. Services are even more coarse-grained than components.

If the learning object research community is to pursue experience from the software industry to inform reuse of learning resources, the question of grain size might be one line of inquiry. I am, however, hesitant to advocate such an approach. Reusing software components in order to improve productivity and software quality in the production of computer systems is very different from reusing learning resources in order to reduce development



cost and improve the quality of learning. One central aim in the software industry approach to reuse is to reduce complexity by “black-boxing” functionality. Learning objects, however, are “white boxes”; transparency into the content is of central concern when evaluating learning objects.

### 3.1.3 The Shareable Content Object Reference Model

The Shareable Content Object Reference Framework (SCORM) is emerging as the predominant approach to standardization among early adopters of learning object technology (Edmonds & Barron, 2002). These early adopters are primarily concerned with corporate training, or training in the US military. But SCORM is also becoming relevant for formal educational institutions. A large number of vendors of Learning Management Systems (LMS) and authoring tools claim to be compliant with SCORM. Examples of products include IBM Lotus Learning Suite, Saba Enterprise Learning Suite, Blackboard Academic Suite, ClassFrontier, WebCT, TopClass, Lectora, and OnCue. These are systems that are used in schools and universities worldwide.

The SCORM is developed and maintained by the Advanced Distributed Learning Initiative (ADL). ADL was launched in 1997 by the US Department of Defense and the White House Office of Science and Technology Policy. The mission of ADL is to “provide access to the highest quality education and training, tailored to individual needs, delivered cost-effectively anytime and anywhere” (ADL, 2004d, p. 1-3). SCORM is ADL’s foundation for accomplishing these goals. With SCORM, ADL “aims to foster creation of reusable learning content as ‘instructional objects’ within a common technical framework for computer-based and Web-based learning” (Ibid.). This technical framework is described by a set of harmonized guidelines, specifications, and standards from multiple organizations. Important contributors to SCORM include IMS, IEEE, AICC, and ARIADNE. SCORM covers three main topics, described in the ADL “technical books”: the *Content Aggregation Model* (ADL, 2004a), *Sequencing and Navigation* (ADL, 2004c), and the *Run-Time Environment* (ADL, 2004b). In addition, an overview of SCORM is presented in a separate document (ADL, 2004d). The Content Aggregation Model book (CAM) is of special interest here, as it is concerned with standardized representations of learning materials.

The SCORM CAM describes the components used in a learning experience, how to package those components for exchange between systems, how to describe those components to enable discovery, and how to define sequencing information for the components. The con-

Content model is made up of assets, sharable content objects (SCOs), activities, content organizations, and content aggregation. *Assets* are the most basic learning resources, such as GIF images, MP3 audio, HTML fragments, or Flash objects – any data that can be rendered within a Web browser or Web-based application. An asset can be composed of other assets. *Sharable Content Objects* (SCOs) are collections of one or more assets, and are the smallest elements of a learning resource that can be tracked by a Learning Management System (LMS). To facilitate reuse across multiple learning contexts, SCOs should be independent of any learning context and should be relatively small units. The next level in the hierarchy is that of *content organization*, which describes the intended use of the content within a hierarchy of activities, and includes sequencing information. SCORM supports exchange of learning content between systems through the structure of *content aggregation*. Figure 4 shows an example of a SCORM content organization.

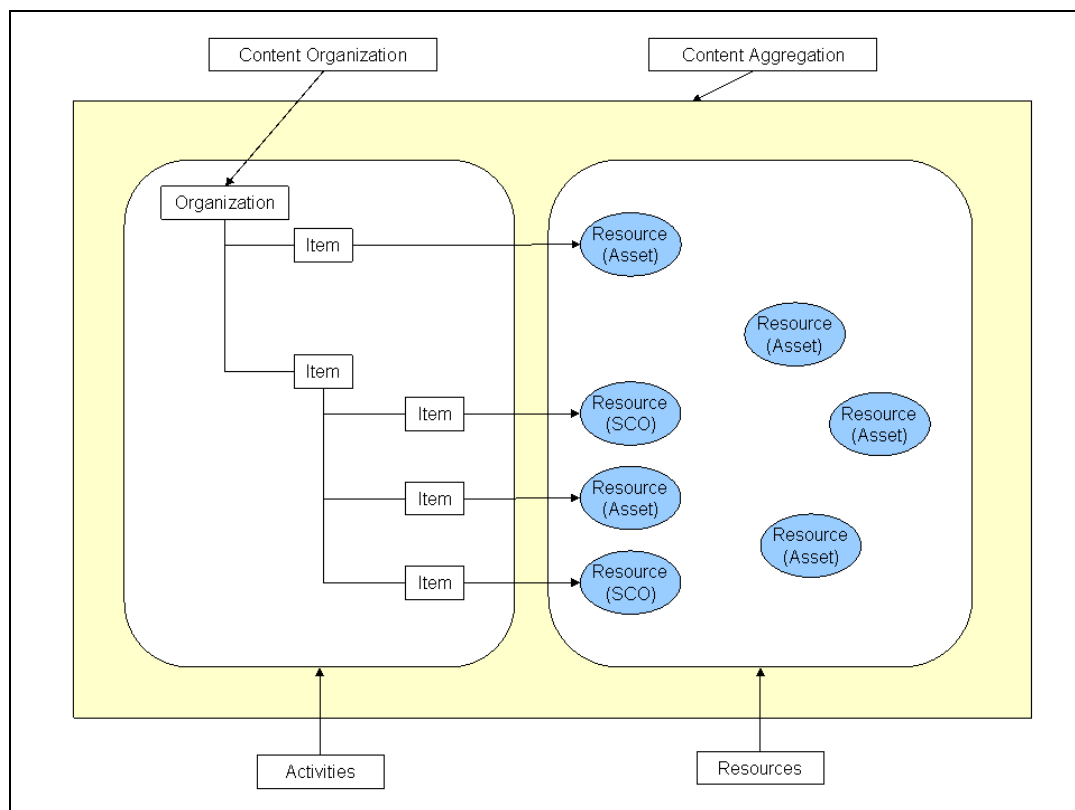


Figure 4: A SCORM Content Organization<sup>21</sup>

One of ADL’s goals with SCORM is to provide specifications that are neutral with respect to pedagogy. In the previous version of the CAM, this is explicitly expressed as follows: “The SCORM Content Aggregation Model represents a *pedagogically neutral* means for designers and implementers of instruction to aggregate learning resources for the purpose

<sup>21</sup> The figure is reproduced from (ADL, 2004a, p. 2-5).

of delivering a desired learning experience” (ADL, 2001, p. 2-3, italics added). In the current version, the phrase ‘pedagogically neutral means’ is replaced with ‘learning taxonomy neutral means’ (ADL, 2004a, p. 1-8).

The value of this approach is questioned. For example, Friesen concludes that “it is important to recognize that objects and infrastructures for learning cannot simultaneously be *both* pedagogically neutral *and* pedagogically valuable (Friesen, 2004b, p. 69). One of the architects of SCORM, Dan Rehak, is reported to have said during an IMS special briefing for implementers that “SCORM is essentially about a single-learner, self-paced and self-directed. It has a limited pedagogical model unsuited for some environments.” Further, he said that “SCORM has nothing in it about collaboration. This makes it inappropriate for use in HE [Higher Education] and K-12” (Kraan & Wilson, 2002). ADL’s model of a learning process shown in Figure 5, as expressed by Slosser in the presentation “ADL and the Sharable Content Object Reference Model” (Slosser, 2001) gives weight to Rehak’s statement.

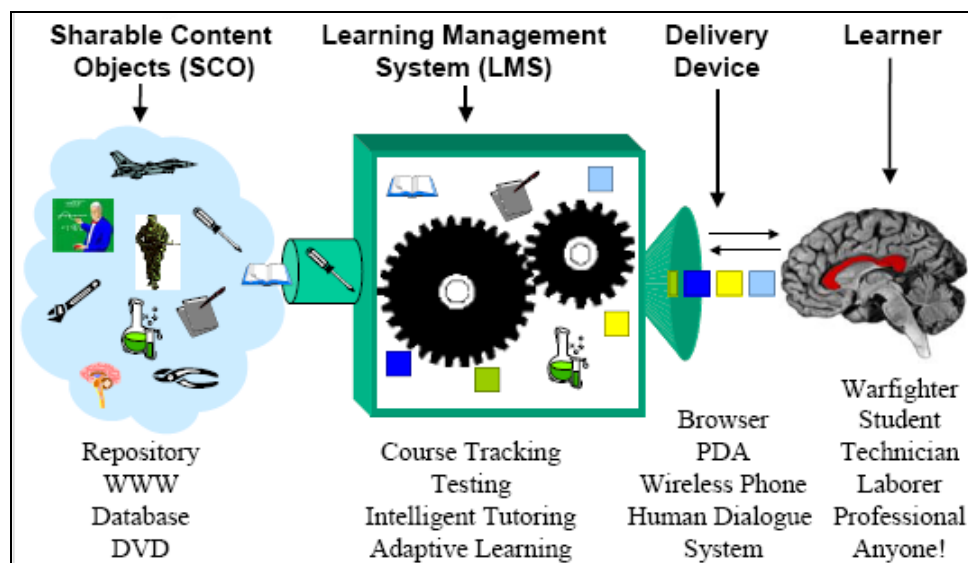


Figure 5: The ADL model of a learning process

Several authors share the concern that SCORM builds on ideas about learning that are at odds with current research on learning (Hoel, 2003; Koper & Olivier, 2004; Welsch, 2002; Wiley, 2003). Koper and Oliver present a typical example of this line of reasoning:

Most current open eLearning specifications and platforms available for course development and presentation can only represent courses that are restricted to a certain type of pedagogy that can be summarized as: in order to learn, a single learner has to work through a sequence of learning objects. The underlying assumption is that learning is a process of consuming content. Teaching is envi-

sioned as the art of selecting and offering content in a structured, sequenced way, and of tracking the learner's progress and assessing the acquired knowledge. Current educational practice is more complex and advanced than this. (Koper & Olivier, 2004, p. 97).

I do share these authors' concerns. However, my theoretical position emphasizes analyses of situated activity. The criticism of SCORM I have discussed in this section does not address this level of analysis. There is a lack of research that goes beyond abstract discussions; a lack of *empirical* research that addresses the specifics of the SCORM framework in relation to particular learning situations.

The most important application area for SCORM is currently skill-based training. IMS Learning Design is a more recent specification. With an ambition to enable diversity in educational design, its scope is different from SCORM, and it should not be understood as a direct replacement for SCORM. IMS LD is presented and discussed in the following section.

### 3.1.4 IMS Learning Design

The IMS Learning design specification (IMS, 2003a, 2003b, 2003c) was created to promote exchange and interoperability of e-learning materials, with a focus on facilitating reuse of teaching strategies and educational goals. A key task of the working group behind IMS LD is “the development of a framework that supports pedagogical diversity and innovation” (IMS, 2003b, p. 4). The specification is based on the Educational Modeling Language (EML) from the Open University of the Netherlands (Oliver & Tattersall, 2005). In their motivation for EML, the architects argue that an exclusive focus on learning objects is problematic:

In our analysis, the major problem with the learning objects model as it is applied until now, is that learning objects are not typed to their usage in the context of a unit of study. To put it in another way; there is a lack of a containing framework. The learning object model express a common overall structure of objects within the context of a unit of study, but does not provide a model to express the semantic relationship between the different types of objects in the context of use in an educational setting. As a result, the learning object model also fails to provide for a model of the structure of the content of the different objects. The typing of objects also varies according to the different pedagogical stances, so there is a need for a meta-model to describe the relationships. (Koper, 2001, p. 5).

This addresses the issue that the learning object approach is intended to provide context-free learning resources. How, then, are these resources contextualized? McCormick (2003) states that “efforts to build into Learning Objects (LOs) a definite pedagogy are doomed to failure. Past experience of the development of LOs indicates that low-level and unsophisticated views of learning are encapsulated in them.” (Ibid, p. 2). McCormick argues that the pedagogy should be ‘put’ elsewhere, in the learning environment constructed by the teacher. EML, and later IMS LD, was designed to facilitate reuse of such contexts. One fundamental idea is to associate educational content with information describing its instructional strategy, which can be used for adapting the content to a pedagogical approach that is different from the one for which it was designed. “By labeling the strategy and the components of the strategy in a common, machine-readable manner, the context of a learning opportunity can be managed separately from the content itself” (IMS, 2003a, p. 4).

This does not represent a rejection of the concept of learning objects. “It is important to reuse learning objects, but we must bear in mind that they are not courses; they are the resources needed to perform learning activities. Reusing a learning resource in a new course still requires us to integrate the object into the course activities and method.” (Koper, 2005, p. 12). IMS LD represents an approach where learning resources are referred to in the learning design, meaning that learning objects can be replaced without altering the learning design. Learning resources are understood to be both digital and non-digital learning objects, as well as services needed during the teaching-learning process. Services can be discussion forums, chat rooms, monitoring tools, search facilities, etc.

The objective of IMS LD is to provide a containment framework of elements that can describe any design of a teaching-learning process in a formal way. This is achieved by providing a ‘meta-language’ which can be used to describe a wide range of pedagogical approaches. This meta-language is based on an extensive examination and analysis of many pedagogical approaches, carried out by the OU of Netherlands (Koper, 2001). In the meta-language, a relatively small vocabulary is used to express what the various pedagogical approaches ask of the learners and support staff in concrete terms. Generally, a learning design describes the way “people in specific groups and roles engage in activities using an environment with appropriate resources and services” (Oliver & Tattersall, 2005, p. 21). The IMS LD is based on the metaphor of learning design as the script of a theatrical play. A person gets a *role* in the teaching-learning process, which can be a *learner* or a *staff* role.

The person works towards certain *outcomes* by performing *activities* within an *environment*. The environment consists of the appropriate *learning objects and services* to be used during the performance of the activities. Methods specify the dynamic aspects of the learning design. A method is designed to meet *learning objectives*, and presupposes certain *prerequisites*. The method consists of one or more concurrent *play(s)*; a play consists of one or more sequential *act(s)* and an act is related to one or more concurrent *role-part(s)* (IMS, 2003b, p. 11).

IMS LD specifies three levels of implementation and compliance. This division of the specification is done to define a complete core that is as simple as possible, and then to define extensions that capture more sophisticated features and behaviors. Level A includes the features discussed so far. Level B adds *properties* and *conditions*, which enable personalization and more elaborate sequencing and interactions based on learner portfolios. Level C adds *notifications*. A notification is triggered by an outcome and can make a new activity available for a role to perform (IMS, 2003b, pp. 4-5). Figure 6 (IMS, 2003b, p. 10) shows a conceptual view of IMS LD modeled in UML, with emphasis on the functional relationships between the classes.

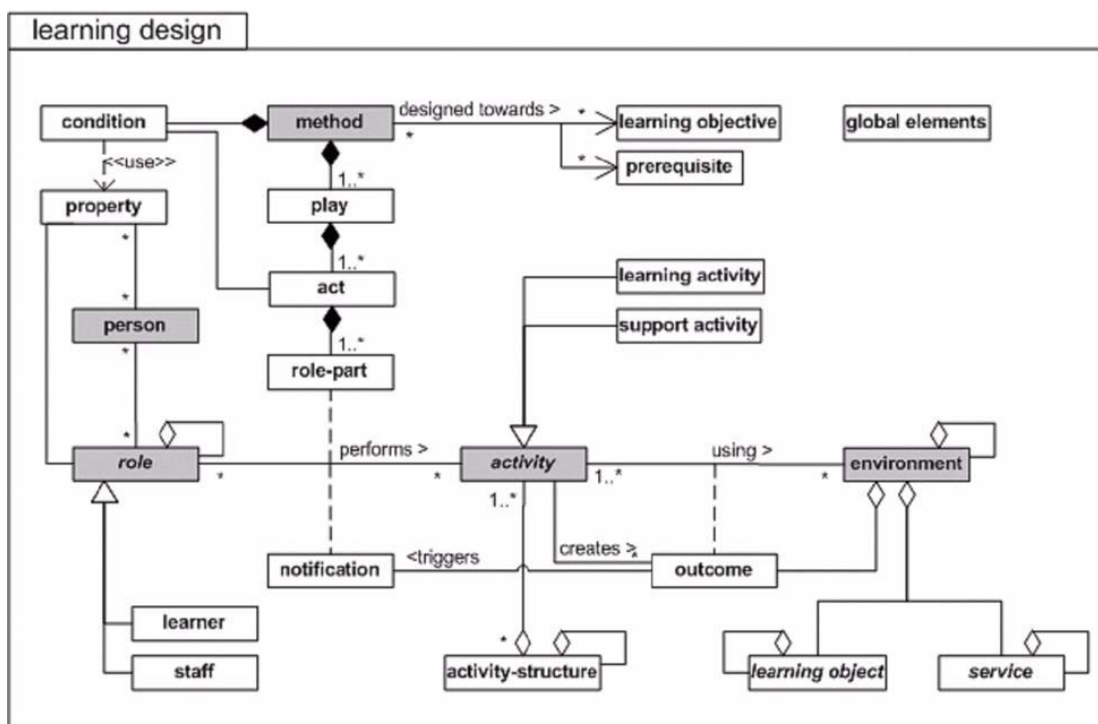


Figure 6: Conceptual model of IMS LD

The IMS LD specification is complex, and it requires a substantial supporting framework of components and services if it is to transform the experience of learning technology

(Wilson, 2005). Two of the key architects of the specification state that “the principles and standards are defined, but most of the tooling still has to be developed” (Koper & Tattersall, 2005, p. vi). CopperCore<sup>22</sup> provides one important part of a supporting framework for LD. It is an open source IMS Learning Design engine, implementing the ‘business logic’ of the specification. That is, CopperCore handles synchronization and personalization workflow issues in the runtime environment. Another central LD implementation project is RELOAD<sup>23</sup>. This open source project has developed the Learning Design Player, which is built on CopperCore. RELOAD has also developed the Learning Design Editor, an authoring tool which supports the full IMS LD specification. Another early learning design system is LAMS<sup>24</sup>. This system, which is also open source, is based on EML and IMS LD, but it does not fully comply with either (Dalziel, 2003). IMS LD is currently not widely supported in commercial virtual learning environments and learning content management systems. The elive LD Suite from elive<sup>25</sup> is one of the few commercial systems available.

As mentioned before, the objective of the Learning Design specification is to “provide a containment framework of elements that can describe any design of a teaching-learning process in a formal way” (IMS, 2003b, p. 8). However, when investigating the capacity of IMS LD for formalizing collaborative learning scripts, Miao et al. (2005) found several major difficulties. A collaboration script is a set of instructions specifying the roles of the group members and the nature and timing of their collaborative activities in solving a problem (O'Donnel & Dansereau, 1992). The issues identified are related to how LD models groups, actor-generated artifacts, dynamic processes, complex process structures, and varied forms of social interactions. To overcome these limitations of IMS LD, Miao et al. suggest a scripting language for CSCL scripts, i.e. computational representation of collaboration scripts.

In summary, IMS LD addresses reuse of teaching strategies and educational goals, and it carries the promise of supporting a wide range of pedagogical approaches. However, some shortcomings with regard to collaborative learning approaches are identified. The

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<sup>22</sup> <http://coppercore.org/>

<sup>23</sup> <http://www.reload.ac.uk/>

<sup>24</sup> <http://www.lamsinternational.com/>

<sup>25</sup> <http://www.elive-ld.com>

specification is complex, and extensive tool support is required for wide deployment. As the specification is quite recent, this support is currently modest.

### 3.1.5 Learning technology standardization and reuse

As noted in Chapter 1, the two main drivers behind learning technology standardization are the prospect of improving cost-efficiency with respect to development and deployment of learning technologies, and improving the quality of learning experiences. These apply to both SCORM and IMS LD. These perceived benefits of standardization can be obtained through reuse of digital learning material. “Reuse is necessary to gain economic benefits from educational technology.” (Duncan, 2003, p. 12). The overview of the field of learning technology standardization provided in this chapter shows that discussions of reuse are primarily concerned with properties of reusable learning materials. They need to be provided with metadata in order to facilitate organization to ease discovery, they need to have an appropriate grain size, and they need to be interoperable or portable.

I have asserted that the phenomenon of reuse is not well developed in the discussions on standardization. Reuse of learning material is generally understood to involve materials that are created once and used numerous times in various contexts, in the form of learning objects (Downes, 2004; Duval & Hodgins, 2004; Littlejohn, 2003a; Wiley, 2000). Rehak and Mason (2003) associates reusability of learning objects with the ability to modify and version them for different courses. Such customization of learning objects is sometimes referred to as repurposing (Treviranus & Brewer, 2003). Doorten and colleagues distinguish between three types of reuse: ‘reuse as is’, repurposing (reuse in a different context), and customization (reuse with adaptations made) (Doorten, Giesbers, Janssen, Daniels, & Koper, 2003). This conceptualization has the same scope as the more generally used understanding, but provides more detail. The way Doorten et al use “repurposing” is in conflict with Treviranus and Brewer’s use of the term. Koper defines reuse as “the availability of learning objects for others to use” (Koper, 2003, p. 48), which is consistent with the above conceptualizations. He identifies three levels of reuse: a person reusing something he or she has created, reusing something created by someone else within the same community or organization, or reusing something created by someone from an external community.

My concern about the lack of a more refined understanding of reuse is shared by others (Doorten, Giesbers, Janssen, Daniels, & Koper, 2003; Koper, 2003). Although some reflections on various aspects of reuse have been made, I contend that more detailed analyses of



reuse, carefully grounded in empirical research, will be beneficial for our understanding of this concept. Such an understanding can be of value in both deployment and development of standards for learning resources. My inquiries into reuse have been carried out in educational settings within the domain of computer supported collaborative learning, presented in the following section.

## 3.2 CSCL

The Computer Supported Collaborative Learning (CSCL) community addresses the reciprocal relationship between different forms of technology and human learning. The uniqueness of the field is characterized by its double-edged focus on the design of ICT as a mediator for change, and the focus on understanding learning as change over time (Wasson, Ludvigsen, & Hoppe, 2003a). Lipponen, Hakkarainen, and Paavola (2004) suggest that CSCL is “focused on how collaborative learning, supported by technology, can enhance peer interaction and work in groups, and how collaboration and technology facilitate sharing and distributing of knowledge and expertise among community members.” (Ibid, p. 32). Koschmann proposes a definition of what constitutes CSCL research: “CSCL is a field of study centrally concerned with meaning and the practices of meaning-making in the context of joint activity and the ways in which these practices are mediated through designed artifacts.” (Koschmann, 2002, p. 20). Commenting on this definition, Stahl (2002a) argues that ‘the practices of meaning-making’ does not “so much entail looking at *individuals*’ practices in social settings, as it focuses on the essentially *social* practices of joint meaning-making” (Ibid, p. 1). Later, Stahl clarifies this position by suggesting that “meaning-making can be treated as an essentially social activity that is conducted jointly – collaboratively – by a community, rather than by individuals who happen to be co-located.” (Stahl, 2003, p. 523). Stahl (Ibid.) also draws our attention towards interpretation of the role of artifacts in Koschmann’s definition. Artifact mediation can be seen more generally than just transmission of personal opinions through a technological artifact. For me, artifact mediation means more than communication through artifacts. Based on a socio-cultural understanding, I see purposeful human activity as fundamentally mediated by artifacts.

CSCL is an interdisciplinary field where technology meets psychology, philosophy and pedagogy, and it brings together instructional designers and software developers, educational psychologists, learning theorists, computer scientists, and sociologists (Lipponen,

2002). CSCL is built on research traditions that are devoted to understanding language, culture, and other aspects of social settings, including anthropology, sociology, linguistics, and communication science (Koschmann, 1996a). Recognizing the variety of theoretical reference frames in CSCL, Wasson & al. (2003a) suggests that creating a unified platform of ontological and epistemological assumptions is neither feasible nor desirable. Innovative educational practice, they assert, “shows more similarities between scenarios inspired by supposedly quite different ‘schools of thought’ than one might expect from following the theoretical disputes.” (Ibid, p. xvii). The diversity of the CSCL field is also evident in various approaches to collaborative learning studied by CSCL researchers. These include constructivist, cultural-historical, and shared cognition approaches (Dirckinck-Holmfeld, 2002). Collaborative learning can be broadly defined as “a *situation* in which *two or more* people *learn* or attempt to learn something *together*.” (Dillenbourg, 1999, p. 1). My understanding of this definition is that it indicates an emphasis on individual learning, which is problematic with regard to my theoretical position (see Chapter 2). In a socio-cultural perspective, learning is regarded as a fundamentally social process. Stahl (Op cit) proposes that collaborative learning takes place through processes of shared meaning-making, and that this is an essentially social activity that is carried out collaboratively. While this perspective might not capture a shared belief about collaborative learning in the CSCL research community, it resonates with how I conceptualize collaborative learning in my work. The next section expands on my position in the CSCL field.

### 3.2.1 Distributed CSCL

My research interest is within the sociocultural (or cultural-historical) approach to CSCL (see Chapter 2). CSCL research in this tradition is concerned with situations where the collaborating learners are co-located (e.g. Rasmussen, 2005), dispersed (e.g. Furberg & Berge, 2003), mixed-mode, which is a combination of these two (e.g. Sorensen & Takle, 1999), and situations where co-located groups collaborate over distance (e.g. Wasson & Ludvigsen, 2003). My primary interest is in distributed settings, where most of the students’ collaboration is ICT-mediated. This approach to CSCL, sometimes referred to as distributed CSCL (e.g. Sorensen, 2002), has its roots in the two traditions of co-located collaborative learning and distance education (Fjuk & Dirckinck-Holmfeld, 1997).

Most CSCL systems are web-based, used from networked PCs (e.g. Bygholm, 2002). Other platforms include room-based video conferencing (e.g. Svensson, 2002a) and hand-

held devices (e.g. Smørdal & Gregory, 2003). My PhD work is primarily concerned with PC-based distributed CSCL systems. Such systems represent historically new conditions for carrying out learning and teaching activities. Understanding these new conditions represents a complex challenge, and they are constituted by characteristics of the pedagogical approach, subject domain, learning goals, institutional history and practices, organization of the learning activities, the student group, and the technology (Fjuk, 1998). The conditions for distributed CSCL can be systemized in the triadic interdependent relationship between pedagogy, organization, and technology (Ibid.). Digital learning resources are a constituting part of the new conditions for learning and teaching in distributed CSCL. While maintaining a holistic view, my focus in understanding these conditions is on the role of the mediating artifacts with a particular interest in digital learning resources.

Distributed CSCL should be understood as a new phenomenon, relying on its own specific conditions (Fjuk, 1998; Fjuk & Ludvigsen, 2001; Sorensen, 1997). A major strand in sociocultural research on distributed CSCL explores these conditions with studies of social interactions. After more than a decade of work in this area, Sorensen identifies facilitation for dialogue as the most important issue for the research agenda:

The experiences gained with implementation of distributed networked processes evidently has had mixed success. From a perspective on learning as a collaborative phenomenon, the significant problem of establishing an effective collaborative learning dialogue working for knowledge building seems to be the most complex challenge and is a serious problem to address and resolve. (Sorensen, 2005).

One example of a distributed CSCL project is DoCTA, a project where the aim was “to bring a theoretical perspective to the design of ICT technologies that support the sociocultural aspects of human interaction *and* to evaluate its use.” (Wasson & Mørch, 2000, p. 237). This project was carried out in the field of teacher education. Analyses of social interaction in the intervention studies resulted in the identification of four collaboration patterns (Wasson, Guribye, & Mørch, 2000). These show that distributed CSCL environments result in new and different collaboration patterns compared to co-located forms of collaboration (Fjuk & Ludvigsen, 2001).

In a study of social interactions in a networked 3D learning environment, Krange, Larsen, Fjuk, & Ludvigsen (2002) identify two collaboration patterns specific to this environment. The learners participating in this study were 15-year olds, working on the topic of ecological issues. A follow-up study using similar technology was conducted in a secondary

school, where molecular biology was the subject domain. Analyses of use indicated that collaborative processes in the groups were adequate as long as the subject content was relatively straightforward, but tended to break down when the content became more complex (Furberg & Berge, 2003).

More recent work on distributed CSCL in Europe has been brought together in Kaleidoscope, an EU-funded Network of Excellence. The Jointly Executed Integrating Research Project (JEIRP) on conditions for productive learning in networked learning environments has collected prototypical case studies from the research field, and used these as a point of departure for identifying and conceptualizing core issues of relevance for networked learning environments (Dirckinck-Holmfeld, Lindström, Svendsen, & Ponti, 2005). Project COOL has contributed one case to the JEIRP, focusing on using concepts from activity theory as analytical tools for improving pedagogical design of a particular course on object-oriented programming (Fjuk & Berge, 2005). Another case study is concerned with the textual participation of students in asynchronous Computer Mediated Communication in a distance education course, exploring the conditions of learning through engagement and participation (Jonsson, Vigmo, Peterson, & Bergviken-Rensfeldt, 2005). A final example from this JEIRP is the case, “Patterns of Facilitation in Distributed Problem-Based Learning – Pedagogical Approaches to Promote Active Student Participation”, focusing on the role of the facilitator in distributed problem-based learning. Based on facilitators’ discursive actions in a text-based conferencing system, the study identifies two patterns of facilitator scaffolding and discusses them with respect to opportunities for students to express their reasoning (Björck & Lindström, 2005).

The studies I have referred to here are all concerned with analysis of social interactions in distributed CSCL settings. Moreover, they pay particular attention to how the mediating ICTs shape these interactions, as well as taking other aspects of the learning situations into account. A common aim of these studies is to get an understanding of the communicative conditions constituted by the CSCL environments within their particular problem domains. My research on distributed CSCL extends this line of inquiry. With basis in empirical research on university-level introductory object-oriented programming, analyses of social interaction is central for my research on the roles of digital learning resources.

### 3.3 CSCL and learning technology standardization

Standardization represents an opportunity for CSCL researchers to capture the results of their research. It provides the possibility of reifying understanding of what constitutes productive collaborative learning processes, and to facilitate sustainable deployment of CSCL systems in educational practice. This section gives an account of the CSCL community's engagement with the standardization initiatives described in Section 3.1, and discusses some possible directions for how CSCL as a field can approach standardization.

CSCL's interest in learning technology standardization can be traced by a review of literature from this research field. The body of work reviewed consists of the full papers in the proceedings from the six CSCL conferences arranged from 1995 to 2005 and the European conference on CSCL in 2001; the two influential edited volumes "CSCL: Theory and Practice of an Emerging Paradigm" (Koschmann, 1996b) and "CSCL 2: Carrying Forward the Conversation" (Koschmann, Hall, & Miyake, 2002); and volumes 1, 3, and 4 in the Computer Supported Collaborative Learning book series from Kluwer<sup>26</sup>, edited by Pierre Dillenbourg.

Learning technology standardization gained momentum with the release of the first version of SCORM, in January 2000. There are no papers concerned with standardization from CSCL '95 (Schnase & Cunnius, 1995), CSCL '97 (Hall, Miyake, & Enyedy, 1998), CSCL '99 (Hoadley & Roschelle, 1999), or in the book "CSCL" (Koschmann, 1996b), all predating SCORM. The book "CSCL 2" (Koschmann, Hall, & Miyake, 2002) and volumes 1 and 4 in the CSCL book series (Andriessen, Baker, & Suthers, 2003; Goodyear, Banks, Hodgson, & McConnell, 2004) also do not contain any chapters on standardization.

In Euro CSCL '01 (Dillenbourg, Eurelings, & Hakkarainen, 2001), there is one full paper discussing the IEEE LOM standard. Monthienvichienchai, Sasse, and Wheeldon (2001) discuss this metadata standard with respect to the authoring of teaching materials by language teachers.

In the proceedings of CSCL '02 (Stahl, 2002b), there is also one paper related to standardization. Brecht, Chung, and Pea (2002) propose an educational modeling language, CML, to generate a mapping from activity design to its implementation. Although EML /

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<sup>26</sup> Volume 2 in this series is the proceedings from CSCL 2003.

IMS Learning Design (see Section 3.1.4) is not mentioned in this paper, the concept is consistent with these specifications.

The proceedings from CSCL '03 (Wasson, Ludvigsen, & Hoppe, 2003b) contain two papers on standards. Allert, Richter, and Nejdil (2003) argue convincingly that educational metadata (like IEEE LOM elements) will always reflect specific learning paradigms. Inspired by the evolution of the Semantic Web, they propose a situated approach where metadata is assigned to learning services, not learning objects. Caeiro, Anido, and Llamas (2003) discuss the IMS Learning Design specification. With the help of concepts from Activity Theory and Workflow Management Systems, they propose some changes to the specification to provide more flexibility and modularity.

In volume 4 of the CSCL book series (Strijbos, Kirschner, & Martens, 2004), the chapter "CSCL-ware in practice" (de Graaf, de Laat, & Scheltinga, 2004) discusses implementation of CSCL in educational practice. They suggest that learning objects can facilitate both individual and collaborative learning, and provide examples of learning object repositories.

Finally, there are three papers in the CSCL '05 proceedings (Koschmann, Suthers, & Chan, 2005) related to standardization. Miao, Hoeksema, Hoppe, and Harrer (2005) analyze the suitability and limitations of IMS LD for modeling collaborative learning processes. Based on this analysis, they suggest a CSCL scripting language. Kuhn, Jansen, Harrer, and Hoppe (2005) describe a session management system for setting up collaborative classroom scenarios, and discuss the specifications of scenarios with respect to IMS LD. Hoppe et al. (2005) touch upon metadata for content in a learning object repository, part of a system based on work in the areas of social navigation and recommender systems.

This literature review reveals a modest, but growing interest in learning technology standardization in the CSCL field. Early work on learning objects and standardization came out of the e-learning industry, with focus on requirements for training in large corporations and the US military. These issues have not been of central concern for CSCL. In this perspective, the moderate interest from the CSCL community is not surprising. Another factor that also might explain CSCL's low engagement with standards is how CSCL systems are used in educational institutions. Many such systems are developed for testing assumptions about learning or exploring new technological opportunities. They are often used in intervention studies for a limited time span, in design experiments or sometimes in controlled laboratory settings. Because standards respond to issues arising out of large-scale use, they might seem irrelevant for experimental CSCL systems. However, as the

field matures, we can expect (or hope for) CSCL systems to be increasingly used as an integral part of everyday activities in educational institutions. Such a development will probably bring the issue of standardization to bear on production-scale CSCL systems, which in turn might increase the CSCL community's interest in – and commitment to – existing and new learning technology standards and specifications.

One possible approach to standardization for CSCL might be collaboration scripts. A collaboration script is a set of instructions specifying how group members should interact and collaborate to solve a problem (O'Donnell & Dansereau, 1992). This concept is discussed by several CSCL researchers (Jermann & Dillenbourg, 2003; Kollar, Fischer, & Slotta, 2005; Miao, Hoeksema, Hoppe, & Harrer, 2005; Weinberger, Fischer, & Mandl, 2002). Dillenbourg (2002) suggests that one way to enhance the effectiveness of collaborative learning is to structure interactions by engaging students in well-defined scripts. “On the one hand, the definition of scripts constitutes a promising convergence between educational engineering and socio-cultural approaches but, on the other hand, it drifts away from the genuine notion of collaborative learning” (Ibid, p. 61). However, most CSCL research on collaboration scripts does not discuss a standardized approach to implementing them. One notable exception is Miao & al. (2005), who propose a CSCL scripting language (see Section 3.1.4). Bote-Lorenzo & al. (2004) also discuss IMS LD as a way to implement collaboration scripts. The work on collaboration scripts in CSCL and the efforts being put into IMS LD might inform each other, and research on this might lead to increased opportunities for CSCL educators to share their practices.

Collaboration scripts can be regarded as artifacts where knowledge of productive collaborative processes is reified, and they can be used in ICT-mediated learning environments as scaffolds for students in their collaborative learning processes. From such a perspective, they are similar to pedagogical agents. Pedagogical agents are autonomous software agents that support learning in virtual environments (Johnson, Rickel, Stiles, & Munro, 1998). Mørch, Jondahl, and Dolonen (2005) discuss pedagogical agents in the context of distributed CSCL. They describe pedagogical agents as “autonomous agents reacting to changes in their environment, communicating in rudimentary ways with other agents, communicating directly with users, and being adaptable by end users.” (Ibid, p. 42). Other examples of research on pedagogical agents in CSCL can be found in the conference proceedings from CSCL 2002 (Constantino-González & Suthers, 2002; Jaques, Oliveira, & Vicari, 2002; Ogata, Matsuura, & Yano, 2002) and CSCL 2003 (Ayla, 2003;

Baggetun & Dragsnes, 2003; Dolonen, Chen, & Mørch, 2003). Pedagogical agents are not discussed as reusable learning resources in the literature, and I am not aware of any initiatives that seek to provide standardized descriptions of them. However, they can be designed as software components that can be used in component-based (see Section 3.1.2) CSCL systems.

Monthienvichienchai, Sasse, and Wheeldon (2001) briefly mention that language teachers reuse materials at a much lower level of granularity than the LOM metadata schema would suggest. Apart from this, reuse is not discussed in any of the CSCL papers reviewed in this section. As I argue in the introduction to this thesis, I regard understanding of reuse as of profound importance for standards deployment. I expect the work presented in this thesis to help raise awareness of this important issue in the field of CSCL.



# 4 Method

This chapter gives an account of the research method employed in the PhD project. Section 4.1 describes the research design and its rationale, and gives an overview of the empirical part of the work. Section 4.2 provides an overview of how my data material has been used in the various research papers, and discusses how the data have been analyzed. This chapter concludes with a discussion of the research method with respect to reliability, validity, and generalizability.

## 4.1 Research design

Information Systems (IS) research has its roots in natural sciences, and is dominated by positivist approaches to research relying on quantitative methods (Chen & Hirschheim, 2004; Orlikowski & Baroudi, 1991). The clear-cut distinction between research being either qualitative or quantitative is fading (Alvesson & Sköldbberg, 2000; Creswell, 2003), and interpretive studies have become more frequent in IS research – especially in Europe (Mingers, 2003; Walsham, 1995a). The interpretive strand in IS research is founded on a growing orientation towards social issues related to computer based information systems:

We are living in a period of transition – a search for a new paradigm for information systems (IS) is going on. New research approaches, based on different assumptions, are emerging, and the discussion is being broadened and intensified. At the core of the debate lies the question of how to handle contextuality in IS design and therefore in IS research. It now seems to be generally accepted that designing the technical ‘core system’ alone is insufficient, and that in order to design and implement a successful IS some kind of ‘context’ has to be taken into account – a context that includes people and their relations. Thus, the question is how to obtain reliable, useful results when the object of study belongs – at least partially – to the realm of the social sciences. (Kuutti 1999, p. 360)

In my research, the approach to taking context into account is founded on a sociocultural perspective, as discussed in Chapter 2. The central study object in my research has been reuse of learning resources. I have studied both learning and teaching as *activity*; it is the students’ and teachers’ engagement with learning resources that have been important for me. A sociocultural approach begins with “the assumption that action is mediated and that it cannot be separated from the milieu in which it is carried out” (Wertsch, 1991, p. 18).

This is consistent with the view on systems development that regards the relationship between intended and actual use of artifacts as non-deterministic (Orlikowski, 2000; Winograd & Flores, 1987). A sociocultural perspective thus gives priority to studies of technology in use, and a focus on human interpretations and meanings situated in the context of the activity. In IS research, “the vehicle for such ‘interpretive’ investigations is often the in-depth case study, where research involves frequent visits to the field site over an extended period of time.” (Walsham, 1995b, p. 74). Further, my studies are exploratory, in that they address issues that are not well understood. Based on this, the research is organized as case studies. The case study as a research strategy “allows investigators to retain the holistic and meaningful characteristics of real-life events” (Yin, 2003, p. 2), and it is well suited for exploratory studies that focus on contemporary events. (Ibid.)

A case study “examines a phenomenon in its natural setting, employing multiple methods of data collection to gather information from one or a few entities (people, groups, or organizations). The boundaries of the phenomenon are not clearly evident at the outset of the research and no experimental control or manipulation is used.” (Benbasat, Goldstein, & Mead, 1987, p. 370). Interpretive case studies in IS research draw widely on research techniques from the ethnographic research tradition in anthropology (Walsham, 1995b). Important sources of data include interviews, documents, archival records, observation, physical artifacts (Yin, 2003), informal conversations (Hammersley & Atkinson, 1995), and visual images (Creswell, 2003). The various kinds of data sources for my research are presented in the case descriptions below.

My research design is made up of one pilot study, two case studies at the University of Aarhus, Denmark, and one case study at the University of California at Berkeley, USA. The two Aarhus studies might be considered as one embedded case study, consisting of two embedded units of analysis (Yin, 2003). These studies are carried out on the same course, over two semesters. The student cohorts are different in the two semesters, and a new teacher was responsible for the second instance of the course. The transition between the two semesters is of special interest with regard to reuse. However, because this is discussed in the second Aarhus case, I present my research design as a multiple-case design comprised of three holistic case studies as well as a pilot study. These are described below.

### 4.1.1 Pilot study: INF 101

The purpose of the pilot case study was to familiarize myself with the practice of use and reuse of learning resources in an educational setting, and to help shape my research agenda. This is a strategy recommended for exploratory studies by Benbasat, Goldstein, and Mead (1987). The pilot study was conducted on the course INF 101, an introductory course on object-oriented programming offered by the Department of Informatics at the University of Oslo. The selection of the research site was basically opportunistic, as I joined a team of COOL researchers who conducted a study on this course at a time convenient for the overall progress of my research project.

The study was carried out in the spring semester of 2003. INF 101 started in January and the last lecture was held in May. During this period, two lectures and two tuition sessions in smaller groups (approx. 10-15 students) were arranged each week. One of the tuition sessions was held in a computer laboratory, the other in a classroom. 212 students signed up for the course, 172 attended the final examination. My role as an observer in this course was that of a peripheral-member-researcher (Adler & Adler, 1994), I was present in the auditorium and the computer laboratory but did not actively take part in the activity. Handwritten observation notes, typed up immediately after the observations, constitute the data from the field work. In addition, these notes include information gathered by informal conversations with the lecturers and teaching assistants during the field work. The COOL research team observed eight hours of lectures, 18 hours of computer laboratory tuition, and two hours of classroom tuition. I observed eight hours of lectures and two hours of computer laboratory tuition.

The research interest of the COOL team was to gain insights on how students come to grips with object-oriented concepts and how course organization influences their learning of programming, and to identify issues that students are struggling with. Results from this study are published in the paper *Learning Object-Oriented Programming* (Kaasbøll et al., 2004). My particular interest was in how I could study use and reuse of digital learning resources by lecturers and students. The outcome of the pilot study with regard to this was a draft of a design for data collection, organized as a case study. One important insight for me was that I could study learning resource reuse without introducing an intervention in the learning situation. By intervention, I mean the introduction of new technological artifacts or work processes that I as a researcher would bring into the situation in order to study the effect. But while the observations I carried out in the lectures helped me under-

stand how the lecturers used learning resources, it became apparent for me that I needed additional data to carry out my inquiries. I needed to understand more about how the various kinds of learning resources had evolved, why they were chosen, and how the students used them outside the shared events constituted by the lectures and computer laboratory sessions. Therefore, in-depth interviews became a central means for my data collection in the subsequent case studies.

#### 4.1.2 Case study I: IOOP 03

The primary purpose of this case study was to explore use and reuse of learning resources, with emphasis on digital learning resources, and to explore the roles of these in ICT-mediated learning environments. The study was conducted during the 2003 autumn semester on the course *Introduction to object-oriented programming* (IOOP) at the University of Aarhus, Denmark. This university-level introductory course on object-oriented programming was organized as a net-based course. The most important reason for selecting this course as a site for the case study was its net-based organization, with extensive use of digital learning resources. Thus, the rationale for selecting IOOP was not an attempt to find a typical or representative case. Rather, the central criterion for selection was to find a case that could help with understanding of my research questions (Stake, 1995). In this respect, IOOP can be regarded as an extreme case (Yin, 2003). This choice is appropriate when the target of generalization is “what may be”, not “what is” (Kvale, 1996). Other factors influencing this choice of case were the topic of the course, object-orientation, the field of study central to the COOL project, and a clearly formulated pedagogical approach, resonating with sociocultural perspectives. This latter issue is of particular interest for my exploration of the roles of digital learning resources in ICT-mediated learning environments.

IOOP has been offered as a campus-based course for more than a decade, and the autumn 2003 semester was the second time it was conducted as a net-based course. This organization was chosen to accommodate the target group: adult part-time students all across Denmark. Eighteen of the 22 students who registered for the course completed it. Three of the students were female, and the ages of the students ranged from early thirties to early sixties, with the majority being in the mid to late thirties. Most students held full-time jobs during the course, many as computer programmers. All students were informed by the teacher of the researchers' presence at the outset of the semester, including an explanation

of the aim and scope of the observations. All the informants signed an informed consent document during the study.

The teacher of the course had several years of experience teaching the campus-based IOOP course, and was one of the two designers of the net-based course. Additionally, one teacher assistant took part. Both the teacher and the teaching assistant also participated in the previous semesters' net-based IOOP course.

The collective activities in IOOP 03 were organized as both co-located and distributed activities. There were three co-located events during the semester, organized as weekend seminars where the participants met on the university campus. A net-based meeting was arranged once a week, 14 in all. These meetings were mediated by a video stream broadcast from the teacher and a text-based Instant Messaging (IM) conference. Recordings of the video streams were made available to the students shortly after the meetings on the course web site. More information on the course design and the various learning resources is provided in papers II through V (See Appendixes).

The study was carried out by COOL researcher and project manager Annita Fjuk and myself. During our observation of the collective activities, we participated as peripheral-member-researchers. The participants were informed about our presence and roles as researchers, and we did not take active part in the social interactions. I observed 10 of the 14 online meetings. The data from these observations consists of field notes, recordings of the video streams (approx. 12 hours), and a complete record of all IM conference interactions (approx. 750 entries). We participated in the second weekend seminar, documenting the activities with field notes and video recordings of selected events (one two-hour lecture and one two-hour session with small-group work in a computer laboratory). This weekend seminar also provided an opportunity for us to socialize with the students and carry out informal conversations, contributing to our background understanding of the context. In addition to the net-based meetings and the weekend seminars, a text-based, asynchronous web discussion forum provided opportunities for the students to collaborate. The 45 postings from this forum are included in our data material.

We conducted semi-structured audio-recorded interviews (Kvale, 1996) with nine students and the teaching assistant, each lasting approximately 30 minutes. These were carried out just after their final examination. The focus of the interviews was how the students had used the various learning resources and their experiences with the collaborative activities during the semester. A one-hour interview with the teacher was conducted during the first

weekend seminar, and a 90-minute interview was conducted at the end of the course. These semi-structured interviews were also audio-recorded. The first interview was primarily concerned with the course design and its rationale, the second with his experiences regarding how the course had been carried out.

Additional data collected during the case study include the learning resources used by the students and all documents published on the IOOP web site, as well as student responses to a questionnaire survey which was part of the regular course evaluation. Finally, I communicated with the teacher and the teaching assistant by phone and e-mail throughout the semester, mostly to clarify issues arising out of the observations and on administrative issues.

The papers reporting on this case study (II through V) and Section 4.2 describe how these data were used in the analyses.

#### 4.1.3 Case study II: IOOP 04

This case study was carried out during the spring 2004 semester of IOOP. The rationale for the selection of this research site was twofold. First, a multiple-case design was chosen in order to construct a more robust research design (Yin, 2003), improving the validity of my research findings (Benbasat, Goldstein, & Mead, 1987). The two IOOP case studies were not intended as comparative studies, but rather as two cases that could inform and enrich each other. For example, an understanding of the reasons for not using a particular resource in IOOP 04 could be informed by findings from IOOP 03. Second, I expected the transition between the two semesters to reveal rich data on reuse because a new teacher replaced the previous one.

I carried out the empirical work alone in this case study. Twelve students participated in the IOOP 2004 semester, nine completed the final examination. Five of the students were female, and the ages of the students ranged from late twenties to late fifties, with the majority being in the mid thirties to mid forties. Most students held full-time jobs during the course. The teaching assistant was the same as in the previous semester. All students were informed by the teacher of my presence as a researcher before I started my involvement, and I presented the purpose of my study at the weekend seminar I attended. All the informants signed an informed consent document during the study.

In a manner similar to the IOOP 03 study, data was obtained by observation of collective activities, interviews and informal interactions with participants, and collection of learning resources and documents from the IOOP web site. I observed 10 of the 14 net-based meetings. Data from these observations consists of field notes, approx. 17 hours of video material, and the complete IM transcripts (approx. 500 entries). The discussion forum contained 191 postings. I participated in one weekend seminar, the second of four, and documented my observations in field notes. After the final examination, I conducted semi-structured interviews with four students (20-40 minutes duration), the teacher (30 minutes), and the teacher assistant (1 hour). The interviews were audio recorded. In addition, I conducted informal conversations with students and faculty during the second weekend seminar and *ad-hoc* e-mail exchanges with the teacher and the teaching assistant throughout the semester.

The findings from the IOOP 04 case study are reported in Paper IV.

COOL researchers carried out a design experiment (Brown, 1992) in IOOP 04. The purpose of this study was to explore some issues identified in the IOOP 03 case study, related to social interaction patterns in the online meetings. I did not take part in the design or execution of this intervention study, but contributed during the analysis. As findings from this study have informed my research, I include a brief description of the design experiment here.

The background, aim, and scope of the intervention were presented at the second weekend seminar in IOOP 04 by the IOOP 03 teacher. Ten students volunteered to take part in the study, which took place in week six of the semester. The students were divided into three groups, and each group was asked to solve the same problem, which was to modify and extend a program. The IOOP 03 teacher guided two groups, and the other IOOP course designer was the facilitator for the third group. The groups worked from various locations, and used the Centra collaborative work application for their joint activities. The work on the problem was carried out in two sessions. The purpose of the first session was that the students should familiarize themselves with the Centra software, establish a shared understanding of the problem to be solved, and agree on a division of work. The aim of the second session, taking place approximately one week after the first, was for the group to arrive at a correct joint solution to the programming task. The first session lasted for approximately half an hour, the second for 40 - 60 minutes. Data was collected by a “re-

ording” feature in Centra, which captured what the participants said and their actions in the shared workspace.

Findings from the IOOP 04 design experiment study is reported in Paper III.

#### 4.1.4 Case study III: SAIL

The third case study was conducted from 1 August, 2004 to 22 December, 2004 at the Graduate School of Education, University of California at Berkeley, during my stay there as a visiting student researcher. I studied the development of a new framework for learning technology, the Scalable Architecture for Interactive Learning (SAIL) project. The project is part of the work conducted by the center for Technology Enhanced Learning in Science (TELS), a US national Center for Learning and Teaching involving seven universities, a nonprofit educational research and development organization, and seven school districts. The aim of the center is to improve instruction in science education. The aim of the SAIL project is to develop an open-source framework for educational technology supporting inquiry-based learning in science education.

The development of SAIL is based on more than ten years of experience with research on inquiry-based science education at UC Berkeley. The learning environment WISE (Slotta, 2002) was developed to test and refine the Scaffolded Knowledge Integration framework (Linn, Davis, & Eylon, 2004). WISE has been used by more than 2000 science teachers and 100,000 students in 30 countries. Due to this extensive use, the research team has encountered numerous challenges relating to scalability of the core technologies, as well as the interoperability of WISE with other learning technologies. The SAIL project was initiated to address these issues.

I selected this case because it gave an opportunity to explore my first research question: How do central learning technology standards and specifications accommodate pedagogical approaches found in educational institutions? One central issue was that the development team had a clear understanding of the pedagogical approach they were designing technological support for. The Scaffolded Knowledge Integration Framework builds on socio-constructivist ideas of learning, where collaborative aspects of learning are regarded as central. This perspective was appropriate for my research agenda, as student collaboration was my major concern with the SCORM specifications. Another important reason for selecting the SAIL case was the development team’s interest in standards for learning technology. They saw this as a possibility for adding a degree of credibility and



standardization to the SAIL framework, and the design team members had often encountered strong statements about the importance of being “SCORM compliant”. I was invited to join the team as an expert on learning technology standards. Thus, I had a more involved role in this case study than the IOOP studies, and I took on the active-member-researcher role (Adler & Adler, 1994).

The development team was located at UC Berkeley and at the Concord Consortium near Boston, Massachusetts. I shared office space with the Berkeley development group. I participated in the weekly meetings between the two groups, arranged by video-conferencing. I also joined the two groups in a four-day design retreat set in Franconia Notch, New Hampshire. Minutes from these meetings are part of my data material. In addition to the *ad-hoc* discussions taking place in our office, important sources of data regarding the development of SAIL were discussions carried out on an e-mail list and the project wiki<sup>27</sup>, where all project documentation is available<sup>28</sup>. In order to obtain an understanding of the practices the SAIL framework is intended to provide support for, I conducted a literature study on inquiry-based learning and the more specific approach Scaffolded Knowledge Integration Framework. I also explored WISE and numerous WISE projects (specific implementations of the WISE framework, with authored and student-generated content) to familiarize myself with the envisioned use of SAIL technology. The SCORM and IMS LD specifications are also part of the data material from this case study.

The findings from this case study are presented in Paper I.

## 4.2 Data analysis

In the previous section, I described the full corpus of my empirical material. The various data sources have different positions in my analyses, and Table 2 provides an overview of the data used for analysis in the various research papers. Entries in the matrix designated with a “P” constitute primary data, while entries designated with an “S” represent data that has been used as supplementary material in the analyses.

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<sup>27</sup> A wiki is a type of website that allows users to add and edit content and is especially suited for distributed collaborative authoring.

<sup>28</sup> The SAIL wiki is located at <http://www.telscenter.org/confluence/display/SAIL/Home>

Case study	Empirical material	Paper I	Paper II	Paper III	Paper IV	Paper V
IOOP 03	Teacher interview I		P	S	P	P
	Teacher interview II		S	S	P	P
	Teaching assistant interview		S	S	P	P
	Student interviews		S	S	P	P
	Online meeting observations		S	P	P	S
	Discussion board postings		S	S	S	S
	Weekend seminar observations		S	S		S
	Informal conversations		S	S	S	S
	Learning resources		P	S	S	P
	Documents from web site		P	S	S	S
	Course evaluation survey		S	S		S
IOOP 04	Teacher interview					P
	Teaching assistant interview					P
	Student interviews					P
	Online meeting observations					S
	Discussion board postings					S
	Weekend seminar observations					S
	Informal conversations					S
	Learning resources					P
	Documents from web site					S
	Recordings from design experiment, session I			S		
	Recordings from design experiment, session II			P		
SAIL	Learning theory literature	P				
	SCORM specification	P				
	IMS LD specification	P				
	Participatory observation	S				
	Design meeting minutes	S				
	Ad-hoc discussions	S				
	E-mail distribution list	S				
	Project documentation	S				
WISE projects	S					

Table 2: Data selection summary

Due to the considerable amount of empirical data material collected in the case studies, it has not been feasible to analyze all the data in equal detail. The data selection has been guided by the theoretical basis for my research, presented in Chapter 2. A central principle in my approach has been to identify contradictions in the activity systems I have analyzed, and these contradictions have given direction for further analyses. In the following sections, I discuss my analytical approach in the IOOP and SAIL studies in more detail.

#### 4.2.1 The IOOP studies

The IOOP studies started with an interview with the teacher of the course, who also had contributed to the course design. The central topic in this interview was the rationale for the various technological and organizational components in the course design, with respect to characteristics of the knowledge domain, the target group of the course, and his ideas about learning. Through this interview, and subsequent informal dialogue, we<sup>29</sup> established an understanding of what the teacher wanted to accomplish with the course, and how he planned to carry it out. This understanding was for us fundamental when we later analyzed what took place during the progress of the course.

Based on the first interview with the teacher, we understood the online meetings to have a central position in the course design. Our observations during the fall 2003 semester and the interviews with the students and faculty at the end of the semester corroborated this view. We therefore took a particular interest in these shared events. When we observed the meetings, and later studied the recordings and the corresponding IM interactions, we found a tension between the teacher's intentions for the meetings and the modest social interactions in them. Guided by this, we studied the students' actions in the meetings by selecting episodes (Linell, 1998) of interactions for more detailed analysis. The episodes we selected were chosen because they represented instances of interaction patterns that were typical for the overall communication. We studied these moment-by-moment interactions by the help of interaction analysis (Jordan & Henderson, 1995).

My theoretical position emphasizes that these interactions need to be understood in context, that the interactions cannot be fully understood without regard to the conditions under which they were carried out. The participants engaged in the meetings by carrying out

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<sup>29</sup> Throughout this thesis, the first-person plural pronoun "we" is used when referring to analysis or other work performed by this author together with colleagues. That is, "we" does not denote the 'editorial we'. Accordingly, the first-person singular pronoun "I" is used when referring to this author's own reflections.

operations in the ICT-mediated learning environment. As properties of the constellation of ICTs used for mediating the students' actions in the meetings constituted important conditions for these, we also included them in our analysis.

In addition to studying selected episodes in the data material, we employed techniques that enabled us to obtain a broader view of the material from the online meetings. The data material we used was the logs from the IM sessions, which constituted a complete record of all the entries made by the participants in the meetings we observed. We coded the entries with respect to topic (Coffey & Atkinson, 1996). The coding scheme was both data driven and informed by theory from computer-mediated communication and distance education. This categorization, where we quantified the occurrence of topics, helped us get an overview of what kind of topics were discussed in the meetings.

The combination of these analyses enabled us to propose a shared object for the students' activities: the creation and maintenance of a community of practice on learning object-orientation. This, in turn, was instrumental for us in describing the activity system the participants were engaged in. The activity system gave us a new perspective on the students' actions, and gave us a new understanding of the role of the online meetings in the course design. Our analyses iterated between the three levels analysis (operation, action, and activity), a process which gave us the opportunity to gain an understanding of the systemic whole of the activities we studied.

Our orientation towards the shared events constituted by the online meetings gave primacy to the data material collected during our observations (meeting recordings, IM logs, and field notes) and the interviews with the participants. This does not mean, however, that we disregarded the other empirical material. We used these materials as supplementary data, contributing to our understanding of the totality of the learning situation. The supplementary data material was also important in creating the interview guides we used for our semi-structured interviews at the end of the semester.

Findings from the analyses of the IOOP 03 online meetings led to an intervention study carried out as a design experiment in the spring 2004 semester of IOOP. The aim of the intervention was to explore how ICT-mediated small-group problem solving could resolve problems with the sparse interaction in the online meetings. We analyzed the recordings of the second session of all three groups. These recordings represented a complete, "verbatim", record of the participants' utterances and actions in the Centra application. Due to our interest in social interaction pattern, we initially focused on who of the participants spoke

when. By systemizing interaction and talk by creating a log of the number and duration of turns for each participant, we were able to see that the three groups had distinct social interaction patterns. The data material also showed that the students' pre-prepared suggestions for solutions in the three groups were distinct with respect to degree of completeness. We then turned to analysis of the content of the interactions, together with the artifacts that were displayed in the shared workspace. With the help of interaction analysis of this material (Jordan & Henderson, 1995), we were able to analyze the reciprocal relationship between the student-generated artifacts, the students' presentation style, and the social interaction patterns.

The IOOP studies of learning material reuse spanned two semesters, fall 2003 and spring 2004. The analytical process started with collecting data on which learning resources were used in the IOOP 03 semester. With the exception of the textbook and the accompanying BlueJ development environment, all materials were available on the IOOP web site. The learning resources themselves represented important data, but in addition we needed to understand how and when they were created, and who created them. The interviews with the teacher were the primary sources for information on this. Through these interviews, we established an understanding of the "history" of the learning resources, and how they were intended to be used in the IOOP course. But we were also interested in how they were actually used by the students and the teaching staff during the semester. We had access to parts of this use through our observations of the online activities, but individual self-study also constituted a significant part of the students learning activities. The interviews with the students, where we asked about which learning resources they used, and how they used them, became part of the core data material for this inquiry. I collected data from the IOOP 04 spring semester in a manner similar to in the 03 fall semester. The primary data sources were the learning resources and the interviews with teaching staff and the students.

Based on data from IOOP 03, we categorized the learning resources with respect to the creator's relation to this instance of the course. This categorization had its origin in related research on learning objects and standardization, but the categorization scheme was expanded and refined to accommodate findings in our data material. In my data from IOOP 04, I found occurrences of reuse in all the categories established by the IOOP 03 study. But I also found reuse of elements from IOOP 03 that could not be accommodated in the established scheme. These data led us to add a new dimension to our categorization scheme, where we classified artifact reuse according to abstraction level. This new dimension was

primarily data driven, but it does to some extent reflect hierarchical levels found in learning technology standards.

### 4.2.2 The SAIL study

The analytical focus in the SAIL case study was to evaluate how the two learning technology specifications, SCORM and IMS LD, accommodate technology enhanced inquiry-based science projects. One central aspect of this inquiry was for me to gain an understanding of the requirements of this pedagogical approach with respect to technology. I used literature on inquiry-based learning, and the particular approach represented by the Scaffolded Knowledge Integration Framework, as primary data material for obtaining this understanding. Empirical data from my engagement with the SAIL technology development team supplemented my understanding from theory, and helped guide my literature study. My other primary data source in this study was the SCORM and IMS LD specifications.

My analytical approach was to carefully examine the specifications, looking for tensions between implications of the specifications and what the development team tried to achieve with their SAIL framework. When I had identified a set of possible contradictions, I selected some that I expected to be especially problematic and that could potentially have consequences beyond the scope of the particular pedagogical approach I focused on. I then proceeded to sketch SAIL use-case scenarios where these parts of the specifications would come into play. I discussed these scenarios with members of the development team, and made modifications if appropriate. I then revisited the specifications and analyzed how their relevant aspects harmonized with the requirements of SAIL as understood by the designers.

This analytical process was oriented towards conflicts; I searched for problematic elements in the specifications. But I also found elements of the specifications that did not represent contradictions by this process. I discussed these with the development team, and we have proposed how parts of the specifications can potentially be applied productively within the SAIL framework.

## 4.3 Method revisited

In the social sciences, verification of knowledge is commonly discussed in relation to the concepts of reliability, validity, and generalizability (Kvale, 1996). In this section, I reflect on my research method in terms of these three issues.

### 4.3.1 Reliability

Reliability of research is about the consistency, or robustness, of research findings (Kvale, 1996; Silverman, 2001). The issue of reliability thus pertains to how I have collected and analyzed data, described in Sections 4.1 and 4.2. In this section, I discuss reliability of my research with respect to the nature of my data material as well as methodological- and investigator triangulation.

Silverman (2001) recommends an approach where high reliability in qualitative research is associated with low-inference descriptors, which involves recording observations in terms that are as concrete as possible. For example, this involves verbatim accounts of what people say, rather than researchers' reconstructions of the general sense of what a person said.

The major part of my data material from the IOOP case studies is low-inference. The meeting recordings, textual interactions (IM and discussion forum), documents and learning resources, and audio-recorded interviews all provide persistent verbatim accounts of what took place, available to other researchers for inspection. My observation notes are more based on interpretations of what took place, but these are used as pointers into the data material – not as raw data. Similarly, casual interactions with the participants were used as background for interview guides and directions for analysis.

Important data sources in the SAIL case study include literature on learning theory, specifications for learning technologies, and SAIL design documents. These sources are publicly available in books, reports, and on the SAIL wiki. The discussions carried out on e-mail distribution lists do also constitute accurate records, although not freely available for inspection. In addition, the WISE artifact is also a low-inference source of data. The minutes from the design meetings are available on the SAIL wiki, but these are the reporter's summary of his interpretation of what took place, not verbatim transcripts. My notes from the meetings and ad-hoc discussions with the developers at the office have a similar status with regard to reliability.

My interpretation of events in the case studies is based on multiple sources of data, obtained by various methods such as interviews and observations. The full data corpus is described in the Section 4.1. This approach, methodological triangulation, makes it possible to study a phenomenon from various points of view, and thus strengthens the reliability of qualitative research (Benbasat, Goldstein, & Mead, 1987; Stake, 1995; Yin, 2003). In my approach to methodological triangulation, I have not granted equal status to the various data sources in the analytical processes. While various sources have been used to illuminate the same set of research questions, some of the data material has had a core position in the analysis, and other sources have been used as supplementary data. The status of the empirical material in the five research papers is summarized in Section 4.2.

I have collected, selected, and analyzed data from the IOOP 03 case study in collaboration with other researchers from the COOL project. I have also discussed my analyses on the IOOP 04 and SAIL case studies with other colleagues. Working with other researchers can reveal personal biases and preconceived notions on the part of individual analysts (Jordan & Henderson, 1995), and therefore help improve the reliability of the research (Silverman, 2001; Yin, 2003). The question of reliability is a question of whether other researchers would find the same results, and investigator triangulation can substantiate the research findings with respect to this.

In addition to reliability, validity is also part of establishing credibility of qualitative research findings. This is discussed in the next session.

### 4.3.2 Validity

Validity refers to the accuracy of research findings (Creswell, 2003), involving issues of truth and the nature of knowledge. In qualitative research, validity pertains to the degree that a method investigates what it is intended to investigate (Kvale, 1996). Based on an ontological stance emphasizing social construction of reality, the issue of validity becomes a question of the quality of craftsmanship in research – continually checking, questioning, and theoretically interpreting findings (Ibid.). In this section, I discuss validity with respect to my research in terms of respondent validation, ecological validity, the extent of my interview data, and the provision of thick descriptions.

One technique for increasing validity is respondent validation, taking one's finding back to the subjects being studied (Creswell, 2003; Silverman, 2001). I have used this approach in the IOOP 03 case study, where I have discussed my findings extensively with the teacher



of the course. Two of the papers reporting from this case study are co-authored with this teacher. Concerning the other participants in the IOOP case studies, I have discussed my interpretations to a more modest degree. These discussions have mostly taken place during the interviews. I have also discussed my findings in the SAIL case study throughout my involvement with the design team, and the paper reporting from the study is co-authored with the project director of that team. Respondent validation does not in itself guarantee valid research findings. Feedback from respondents cannot be taken as direct validation or refutation of the researchers' interpretations, but they should be taken as yet another source of data (Silverman, 2001). In a similar vein, I have not treated accounts from the participants as simply constitutive of the phenomena they refer to. "It is a distinctive feature of social research that the 'objects' studied are in fact 'subjects', and themselves produce accounts of their world." (Hammersley & Atkinson, 1995, p. 124). I regard the participants' accounts as important resources, but I have not accepted their validity at face value. This means that I have used supplementary data in my analyses of the interview material when this has been possible. For example, I have used transcripts from the IOOP IM sessions to see if these corroborate with participants' accounts of what took place in the online meetings.

Validity is seen as a particular strength of qualitative research (Creswell, 2003). This might especially pertain to ecological validity (Cicourel, 1996; Cole, Hood, & McDermott, 1997), concerning whether the research is carried out in the real-life setting of the study object. With one exception, the data from my IOOP studies was collected in non-intervention studies. This approach gives strength to the ecological validity aspect of my research. I did not observe the participants as they carried out their ICT-mediated activities in their physical environment. Part of the reason for this was the practical difficulties with gaining access to the students' homes. But more important, my studies focused on the shared events – on what took place during the networked meetings and the other shared arenas. However, I do not disregard the importance of the concrete conditions under which the students carried out their actions, and have discussed this with them in the interviews. Data from a design experiment is also part of the empirical material from IOOP. As this represents an intervention (described in Section 4.1.3), it is more problematic with respect to ecological validity. But even though both the teachers and the groupware application were new to the students, they did carry out their activities in their usual environment. The students also worked in groups during the normal progress of the course, and several activities

were carried out in ICT-mediated environments. My involvement in the SAIL case study was more active than in the IOOP studies. But the issue of standards with respect to the SAIL framework was not introduced by me, and did as such not constitute an intervention in the team's design process.

In my exploratory studies, the research questions have been generated and refined as the research has progressed. This means that data collected by, for example, interviews has given directions for which topics that are of interest in my research. It is therefore relevant to reflect on whether the data material is sufficient for exploring these topics when discussing my research design with respect to validity. Concerning interviews, Kvale's advice is to "interview as many subjects as necessary to find out what you need to know." (Kvale, 1996, p. 101). Following the law of diminishing returns, interviews might be conducted until a point of saturation, where further interviews yield little new knowledge. In the IOOP 03 case, I interviewed nine of the eighteen students who completed the course. I regard this as an adequate number of interviews. The interviews provided a rich source of information from the students' perspective, and the amount was manageable for detailed analysis. In the IOOP 04 case, I interviewed four of the nine students who completed the course. Ideally, I would have liked to interview more students. Each interview yielded interesting insights, and more interviews could probably help me get a better understanding of the students' experiences with the course. The reason for not conducting more interviews was due to practical constraints. Because the students lived all across Denmark, I decided to conduct the interviews in connection with the final examination. This was the last time the students met physically. The examination was oral / practical, where each student was examined individually for approx. 30 minutes. I carried out the interviews immediately after their examination, to minimize the inconvenience for my informants. Due to the strict schedule, I interviewed every other student. I made appointments with the informants in advance, and the examination schedule was set up accordingly. This would have given me five interviews, but one informant unexpectedly did not attend the examination. The distributed organization of the course, together with my location in Oslo, Norway, resulted in a rigid interview schedule. A more dynamic approach could have been valuable in the IOOP 04 case, where I could have arranged for extra interviews. Telephone interviews could have been an option, but due to the differences between the Danish and Norwegian languages this would probably be awkward for the students. I found co-location important to overcome these difficulties.

One key to making it possible to ascertain the validity of research is to provide thick descriptions of the case studies (Creswell, 2003; Kvale, 1996). Details of the field study as they were experienced and collected by the researcher enable the reader to follow how the researcher arrived at his or her insights (Klein & Myers, 1999). This includes rich descriptions of the context for the empirical work, documentation of the procedures for collecting and analyzing the data, and presentation of selections of data that are subject to analysis. The IOOP courses and the SAIL project are briefly introduced in Section 4.1, and more fully described in the research papers. The procedures I used in my empirical work are also discussed in Section 4.1 and in more detail in the research papers. My analytical framework is presented in Section 2.2, and accounts of the analytical process are given in Section 4.2 as well as in the research papers. Transcripts of selected extracts from interviews and interactions in the collaborative forums are presented in the papers. Taken together, I expect that these descriptions will make it possible for the reader to follow how I have arrived at my findings, informed by empirical data and literature.

### 4.3.3 Generalizability

The generalizability, or external validity, of research findings entails the question of whether the findings in one context transfer to other contexts. In interpretive research, generalization involves the notion that “unique instances can be related to ideas and concepts that apply to multiple situations.” (Klein & Myers, 1999, p. 75). Interpretive case study research is often concerned with generalization to theoretical propositions (Lee & Baskerville, 2003; Yin, 2003). This kind of generalization “involves a reasoned judgment about the extent to which the findings from one study can be used as a guide to what might occur in another situation.” (Kvale, 1996, p. 233). Criticizing the Cartesian heritage in studies of human cognition, Säljö and Wyndhamn (1996) states that “The challenge for research is to create theoretical constructs – rather than abstractions – that build on this organic relationship between thinking and the world in which human projects take place.” (Ibid, p. 340). Walsham (1995b) proposes four types of analytical generalizations. These should be regarded as “explanations of particular phenomena derived from empirical interpretative research in specific IS settings, which may be valuable in the future in other organizations and settings.” (Ibid, p. 79). The four types of generalizations are: development of concepts; generation of theory; the drawing of specific implications in particular domains of actions; and contribution of rich insight.

The generalizations I have proposed through my analyses are within Walsham's framework, as they are generalizations from empirical statements to theory. There is variance in the scope of my claims, and I discuss my central findings with respect to generalization in Chapter 5. On an overall level, my findings, taken together with related research on distributed CSCL, contribute to the more general research agenda of CSCL in our efforts toward the generation of theory regarding communication and learning in ICT-mediated learning environments. A characteristic of my generalizations is that they often are in the form of suggestions for design of ICT-mediated learning environments. Although this means that I take a normative turn in my argumentation, I do not put forward that these suggestions should be understood as closed answers to my research questions. Design proposals can be implemented in CSCL systems and applied in various learning situations. Experience from such field trials forms a base on which the proposals can be evaluated. The design proposals can be refined and tested for generalizability through further cycles of iterations between design and use. The epistemological status of my design proposals can thus be regarded as well-informed hypotheses, rather than definitive answers.

Kvale (1996) raises the question of who should conduct the analytical generalization: the researcher or the reader? As indicated in the discussion above, I have suggested how the various findings can be generalized. But I do believe that the descriptions of the specific cases from which these findings are drawn are sufficiently rich that they can also enable the readers to evaluate the relevance of the findings to their particular contexts.

I have discussed verification, or the trustworthiness, of my research with respect to reliability, validity, and generalizability. Another aspect contributing to the credibility of research is a foundation in established theory. I have provided reflections on my analytical framework in Section 2.2.

This chapter has provided an account for the research method I have used in my PhD project. In the next chapter, I summarize the findings of this research.

# 5 Research Findings

This chapter presents a summary of the findings from my research. First, I provide a brief recapitulation of the research questions, and an overview of which papers address which research questions. Then I present the main findings from these papers, structured according to the three research questions. Section 5.4 discusses the implications of these findings with respect to the two research areas presented in Chapter 3, learning technology standardization and CSCL. This chapter is concluded with a summary in Section 5.5.

The three exploratory research questions guiding my research, first presented in Section 1.1, are:

**R-I:** How do central learning technology standards and specifications accommodate pedagogical approaches found in educational institutions?

**R-II:** What are the roles of digital learning resources in ICT-mediated learning environments?

**R-III:** How are learning resources reused in educational institutions, and what kinds of resources are reused?

I do not regard the three research questions to be completely separate entities. Rather, they are three lines of inquiry that all inform the issue of reuse of digital learning resources in ICT-based learning environments. In the summary provided in Table 3, I indicate the *primary* research question the various papers address, as well as the empirical study the papers are based on.

	R-I	R-II	R-III
Paper I	SAIL		
Paper II		IOOP 03	
Paper III		IOOP 03 IOOP 04 <sup>30</sup>	
Paper IV		IOOP 03	
Paper V			IOOP 03 IOOP 04

Table 3: Research paper overview

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<sup>30</sup> IOOP 04 design experiment

## 5.1 R-I: Standards and educational practice

My PhD research was originally motivated by an interest in deployment of learning technology standards in institutionalized educational contexts. This issue is addressed by my first research question, R-I:

- How do central learning technology standards and specifications accommodate pedagogical approaches found in educational institutions?

At that time, SCORM was the dominating approach to learning technology standardization. Despite SCORM's claim to be neutral with respect to pedagogy, there seemed to be some implicit assumptions about learning inscribed in the specifications. My concern was that uncritical adoption of SCORM in educational institutions might affect educational practice in unintended and undesired ways. Since the outset of my PhD project, the IMS Learning Design specification has become subject to substantial interest in the field of learning technology standardization. Paper I addresses the first research question by analyzing the applicability of SCORM and IMS LD in one specific domain: inquiry-based science learning. It explores the affordances and constraints of the specifications, and identifies specific constructs and features of the specifications that are problematic with respect to this pedagogical approach.

### *SCORM*

Our analysis of SCORM did not reveal any tensions between the approach to learning objects taken in SCORM and the SAIL design team's requirements for implementing technology support for inquiry-based learning situations. We found using the IEEE LOM standard for providing learning object metadata to be consistent with the SAIL framework. But when collections of de-contextualized learning objects were aggregated into activities and content organizations, tensions appeared. Such aggregation is in SCORM a means for content developers to specify cohesive "units of instruction". These units of instruction are also carriers of instructional methodology; learning objects are re-contextualized. SCORM sequencing and navigation specify how aggregated learning objects may be sequenced for presentation to the learner through a set of learner- or system-initiated navigation events. This specification, however, is not sensitive to events carried out by other than the individual learner. This represents a tension with regard to SAIL inquiry projects, as learning resource sequencing for one learner can be dependent on other group members' actions.

Students engaged in inquiry-based learning are concerned with ill-structured problems – meaning that one does not know or knows only vaguely what would constitute a solution to the problem. This means that technology supports for inquiry-based learning should be open in the sense that they allow for use of resources that are not part of the pre-prepared material. Examples of such open-ended learning resources from WISE include chat rooms, discussion boards, and design collaboratories. Application of such resources is discouraged in SCORM.

The final issue concerning SCORM I will highlight from Paper I pertains to the tracking of student activities. For the SAIL design team, one technology requirement is the capability to track the actions of an individual user within the context of that user's project group activities. SCORM provides rich mechanisms for tracking individual learners' interactions with the learning content within a learning management system. But there is no concept of 'group' in SCORM. This means that it is not possible to identify relations between users, and therefore not possible to aggregate individual user's interaction data into a group's interaction data. In inquiry-based projects, data on individual user's actions are of limited value if they cannot be regarded in relation to the group context.

### *IMS LD*

Through our analysis, we found that IMS LD can accommodate technology-enhanced inquiry science projects as they are envisioned in the SAIL framework. It is possible to specify science projects that are sufficiently flexible to be adapted to specific classroom contexts. It allows for students' un-anticipated use of learning resources, for adjustments to the progress of the projects by both students and teachers, and it accommodates for use of open-ended learning resources. We found that the value added by IMS LD to be primarily related to the ability to be explicit about the instructional approach and learning activities. The specification has potential for facilitating sharing and reuse of emergent best practice on how to implement inquiry-based science projects in classrooms. IMS LD could also help the exchange of projects between those working within the SAIL framework and those outside it.

The descriptive approach taken in IMS LD leaves many detailed issues unspecified. For example, it does not set out to specify the mechanics of delivering a unit of learning, and the process of interpreting content from one model to another is regarded as out of scope. Specification of requirements for run-time environments is thus largely absent. The educa-

tional model and learning activities are modeled in IMS LD, but components such as learning objects and services are modeled outside the specification. This means that IMS LD does not constitute a complete set of specifications for ICT-based learning environments.

### *Conclusions on R-I*

In summary, our analysis revealed that when de-contextualized learning resources are aggregated into larger units, tensions appear between the SCORM specification and the SAIL development team's requirements. Several important issues were found to be problematic, such the ability to express collaborative activities, the tracking of students' activities within a group context, and the accommodation of students' un-anticipated use of learning resources. The analysis also showed that while inquiry-based science projects can be fully described within IMS LD, the descriptive approach taken in this specification leaves many detailed issues unspecified.

Characteristics of inquiry-based science learning include: Learning activities are carried out in a social or collaborative context within an ICT-based learning environment; they occur primarily in a classroom setting; they are student-centered; they are concerned with ill-structured problems; and they often take a concrete problem or situation as a point of departure. These characteristics are not unique to inquiry science projects, but rather represent an approach to pedagogy and curriculum design that is increasingly common across many domains within formal education. Therefore, I regard the findings of the paper to inform the research question of deployment of standards more broadly than for learning situations based on the pedagogical approach discussed in the paper.

This generalization of the findings from the SAIL case study is rather strong. The analysis of SCORM and IMS LD is carried out with respect to one specific approach to inquiry-based science learning: the Scaffolded Knowledge Integration Framework. I claim that our findings are pertinent to other pedagogical approaches sharing a number of characteristics, described above, with this framework. This analytical generalization is built on a specification of evidence which is provided in more detail in Paper I. This account should enable developers of technology support for various pedagogical approaches to judge the applicability of our findings to their specific requirements.



## 5.2 R-II: The roles of learning resources

The exposition of my theoretical position in Chapter 2 makes it clear that I study students' engagement with learning resources in terms of activity. I understand use of these resources as situated with respect to various interconnected aspects of the learning situations, which I analytically systemize in activity systems. Transformation of learning resources into reusable learning objects represents a change that might affect the internal systemic connections in the situation in which they are used. Therefore, an understanding of the role of the learning resources in the systemic whole is of importance for deployment of learning technology standards. This concern is addressed by the second research question:

- What are the roles of digital learning resources in ICT-mediated learning environments?

Paper II provides an account of the IOOP 03 course design. It describes the various components in the design and their rationale in terms of the teacher's intentions. Given my dialectical perspective on design intentions and use, I do not regard the course design to provide a full explanation for the roles of the learning resources. However, I regard the teacher's account of the course design to be an important resource for exploring this research question.

The pedagogical ideas behind the course design have shaped our discussion. According to Sorensen (2005), this is of central concern for research on distributed CSCL: "One of the most prevailing problems encountered in networked distributed collaborative learning concerns the widespread lack of clarity of pedagogical design and practice in terms of stimulating a qualified interaction and CKB [Collaborative Knowledge Building] dialogue." (Ibid, Distributed Collaborative Knowledge Building Online section, para. 2). In Paper II, we describe the apprenticeship-inspired pedagogical approach of IOOP, the course designers' perspective on object-orientation, and the consequential learning objectives. The paper then describes how these principles are operationalized in the course design and the ICT-mediated learning environment. Paper II thus contributes to CSCL by providing an example of how sociocultural theories on learning can inform course design explicitly.

In this section, three main findings informing the second research question are presented. These are findings on the artifacts used for operationalizing the pedagogical approach, the roles of student-generated artifacts, and the roles of the online meetings.

### *Operationalizing the pedagogical approach*

The fundamental pedagogical idea behind the IOOP 03 course design was apprenticeship learning. The teacher's rationale for choosing this approach was his emphasis on the programming process as a central learning objective. He described his pedagogical approach by using the two facets of apprenticeship discussed by Nielsen and Kvale (1997); the person-centered approach and the decentered approach. In the person-centered approach, importance is placed on how apprentices learn by observing the master performing and reflecting on the actions of a profession. In the decentered understanding, the decisive factor is the apprentices' participation in a community of practice, which places more emphasis on social relations between all participants and the structuring of a community's learning resources (Ibid.). The teacher of the IOOP 03 course attempted to implement both these approaches to apprenticeship in the course design. A preliminary analysis reported in Paper II indicated that the person-centered approach to apprenticeship was largely successful, but that the implementation of the decentered approach to apprenticeship was more problematic. This issue was explored further in Paper III.

Our analysis of the online meetings indicated that they mediated the person-centered approach to apprenticeship adequately. This finding is primarily based on data from our interviews with the students, where several students stated that they had gained new understanding of the subject domain by observing how the teacher approached and solved programming problems. However, our analyses of the social interaction in the meetings, discussed in more detail in Paper IV, indicated that the meetings did not mediate the decentered approach to apprenticeship as intended in the course design. The transcripts from the online meetings revealed that there was only modest interaction on the subject domain; the meetings did not develop into a professional discussion amongst the participants. This raised the issue of whether these meetings could be transformed into reusable learning resources, a question treated in Paper IV.

Sorensen (2005) maintains that problems of identification and distribution of teacher-learner roles in ICT-mediated learning processes are of central importance in facilitation of collaborative knowledge building. Paper III offers insights on how the instruments used for mediating the relationship between teacher and learners contributed to shaping this interaction. Despite the design intentions inspired by apprenticeship learning, the interaction pattern predominant in the meetings was that of traditional lectures. Our analysis indicates that a major factor in this was the combination of video streaming and Instant Messaging.

The modest social interaction in the IOOP 03 online meetings represented a contradiction with respect to the teachers' needs for awareness information on the individual learner's understanding and progress. The term "awareness" is here understood to mean an understanding of the activities of others, which provides a context for one's own activity (Dourish & Bellotti, 1992). This finding is in line with other research emphasizing the importance of awareness information in CSCL environments (Cao & Greer, 2003; Krange & Fjuk, 2004).

### *The roles of student-generated artifacts*

The lack of dialogue on the subject matter also represented a contradiction with respect to the decentered approach to apprenticeship, where such interaction is fundamental for learning. In order to address how these two issues could be resolved in an ICT-mediated learning environment, a design experiment was conducted during the 2004 semester of IOOP. An overall conclusion from this intervention study was that small-group problem solving, where the teacher has the dual role of subject domain expert and moderator for the discussion, can facilitate the decentered approach to apprenticeship learning in an ICT-mediated learning environment.

Computer-mediated learning environments represent new conditions for carrying out collaborative learning activities, as compared to co-located activities (Fjuk, 1998; Fjuk & Ludvigsen, 2001; Sorensen, 1997). In distributed CSCL, the nature of these conditions is often explored by the help of studies of social interaction in such learning environments (e.g., Dirckinck-Holmfeld, Lindström, Svendsen, & Ponti, 2005). A common approach for systemizing findings from this strand of distributed CSCL research is to identify collaboration patterns (e.g., Krange, Larsen, Fjuk, & Ludvigsen, 2002; Wasson, Guribye, & Mørch, 2000). Following this tradition, Paper III identifies three patterns of social interaction that developed in three groups working on a modeling task.

In our analysis of the interaction data from the design experiment, we systemized the three groups' interactions into three distinct interaction patterns. I use the term "interaction pattern" here to describe sequences of interactions we found in our data material, and not in a normative sense (as in design patterns) or as a theoretical proposition for general collaborative learning patterns.

In group 1, the proposal for solution that was presented as a point of departure for discussion was not correct. It was presented in an open manner, and we have labeled the ensuing discussion *collective reflections on an individual contribution*.

In group 2, none of the students had prepared a solution. The group discussions proceeded hesitatingly, often not making much progress until the teacher intervened. We labeled this pattern *joint solving of the problem through teacher legitimated actions*.

The proposal presented at the outset of group 3's session was close to correct. The presentation style was similar to a lecture on a correct solution, and the interaction was characterized by a dominating teacher role. We labeled this pattern *monologue*.

We proposed that the students' pre-prepared suggestions for solutions, along with how these were presented, contributed to shaping the collective activity. We suggested that the shared artifacts constitute important communicative instruments for establishing productive collective activities online. This finding directs our attention towards student-generated artifacts. These resources emerge through the unfolding of collaborative learning activities. Discussions on reuse and learning objects are predominantly concerned with pre-produced learning resources. Thus, this finding adds a new dimension to research on learning technology standardization. This aspect of reuse is explored further in Paper V.

### *The roles of the online meetings*

The issue of student activity in the IOOP 03 online meetings was first identified in Paper II and discussed in Paper III. Paper IV focuses on the role of the online meetings in more detail. In the course design, one role of the online meetings was to contribute to the collaborative aspect of the apprenticeship-inspired pedagogical approach. This intention demands active student participation in the meetings. A central measure of collective-oriented activity is the number of IM entries from the students during the meetings. The teacher, the teaching assistant, and several students all shared the view that the IM activity was low. But almost all the students we interviewed pointed to the meetings as one of the important elements in the course design for their learning. This could be accounted for by one other intended role of the meetings: Implementation of the person-centered aspect of apprenticeship. That is, to provide a mechanism for making the actions of the teacher during problem-solving visible for the students. However, the meetings were captured while they were in progress, and the recordings were made available to the students on the course web site shortly after the meetings. Transcripts of the IM dialogues were not distributed

with the meetings. Considering the low IM activity, an argument can be made for considering individual viewing of the recordings as being roughly equal to participation in the online meetings, with respect to learning outcomes on object-orientation. If the recordings are of equal value to participation in the meeting, and the recordings provide greater flexibility for the students, one possibility is to convert the online meetings into pre-produced videos. Such a conversion would represent a transition from the dynamic, shared events constituted by the meetings, to reusable learning resources. But why did most students prefer to engage in the “live event”, instead of viewing the recording at their own convenience?

An analysis of the IM entries, with respect to the topics addressed, provided insights on this question. The students’ actions in the shared events were directed at social and administrative objects, as well as at the subject matter. In Paper IV, we proposed that the shared object of the activity was the creation and maintenance of a community of practice on object-oriented programming. In this perspective, the meetings became an instrument mediating the students’ actions towards the community of practice. Communities of practice are bound together by a collective developed understanding of what the community is about; they are built by the mutual engagement of the participants, and they have produced a shared repertoire of communal resources (Wenger, 2000). This implies that interactions of a social or administrative nature are not only legitimate but they are central parts of constituting the community.

This finding resonates with other research on distributed CSCL. For example, Svensson (2002b) analyzed text-based electronic interaction in a university-level distance education course on mathematics and statistics. He identifies three typified interaction patterns. These, he finds, constitute mechanisms that are instrumental in supporting the key characteristics of a community of practice. Another example is the study of Murchú & Sorensen (2004) on two online Master’s programs in Ireland and Denmark. They conclude that the main tenants of communities of practice are recognized by the students as being an integral part of the collaborative learning process.

This study indicates that the shared events had a meaning for the IOOP students not anticipated in the course design. A transformation of the meetings into learning objects might maintain their function regarding the subject domain. But such a transformation would affect the students’ opportunities with respect to constructing and maintaining their community of practice. This finding substantiates the relevance of the second research question to

the discussion of standardization. It suggests that awareness of the internal systemic connections of the components in a course design is of profound importance when considering redesign of a net-based course with respect to reuse and standardization of learning resources. This more general point I make here is a turn towards implications for design of ICT-mediated learning environments. The analytical generalization is supported by theory. My assertion is founded in a sociocultural perspective, a well developed theory with high inner consistency. The essential issue for me in making the generalization is the sociocultural understanding of mediated action. The artifact mediating the action, in this case the online meetings, fundamentally shapes the action. My generalization is also supported by its consistency with findings from similar studies (Fjuk & Dirckinck-Holmfeld, 1997; Wasson & Ludvigsen, 2003).

### *Conclusions on R-II*

The second research question is concerned with the roles of digital learning resources in ICT-mediated learning environments. The analyses of the IOOP case studies pertinent to this research question focus on the shared events constituted by the online meetings.

Despite the design intentions inspired by apprenticeship learning, the interaction pattern predominant in the online meetings was that of traditional lectures. Our analysis indicates that a major factor in this was the combination of video streaming and Instant Messaging. The modest social interaction in the IOOP 03 online meetings represented a contradiction with respect to the teachers' needs for awareness information on the individual learner's understanding and progress.

Three patterns of social interaction were identified in the IOOP 04 design experiment. The analysis suggested that these were influenced by the students' pre-prepared solutions to the problem they were given. We proposed that these student-generated artifacts, along with how these were presented, contributed to shaping the groups' collective activity.

A central finding was that these meetings had the role of mediating the students' actions towards the creation and maintenance of a community of practice on object-oriented programming. This was a role not anticipated in the course design. Furthermore, a transformation of the meetings into reusable learning objects might maintain their function with respect to the subject domain, but would disrupt social processes that contribute to creating premises for productive learning processes.

## 5.3 R-III: Learning resource reuse

Reuse of digital learning resources is one primary driver for deployment of learning technology standards, and a core issue in the motivation for the standards. The discussion in Section 3.1 shows that the phenomenon is not well studied and understood. This led to the formulation of the third research question:

- How are learning resources reused in educational institutions, and what kinds of resources are reused?

Paper V explores various aspects of learning resource reuse in and across IOOP 03 and IOOP 04. In this section, the findings are presented in terms of a taxonomy of reuse and how learning technology standards address the various forms of reuse systematized in the taxonomy.

### *Learning resource reuse taxonomy*

We identified four categories of reuse in the IOOP 03 case study. These are use of learning resources that are:

1. Developed for intentional learning situations, created and maintained outside of the specific learning situation in which they are used. The textbook, for example, is one such resource.
2. Developed for intentional learning situations, but created and maintained by the teacher of the course. The set of exercises used in this semester is an example of this kind of reuse.
3. Developed for situations other than intentional learning, by a third party. For example the Java Standard Development Kit documentation.
4. Created by the community in the progress of their collective activity of learning object-orientation. Recordings of the online meetings are examples of reuse in this category.

All these kinds of reuse were also identified in the study of IOOP 04. In addition, this study found reuse of learning material developed for the specific course, but not by the current teacher. This can be regarded as a special case of the first category described above. Moreover, the study identified three additional levels of reuse. The secondary level is reuse of course design components. One example of this is the online meetings, composed of the

constellation of ICT used for mediating the meetings, the applications used by the teacher in the meetings, and the pedagogical approach. The tertiary level is concerned with the whole course design, meaning the overall organization of the course, the week as a frame for distinct units, the curriculum, etc. Finally, the quaternary level of reuse pertains to reuse of the pedagogical approach. We have systemized our findings on various kinds and levels of reuse in a tentative taxonomy of learning resource reuse, shown in Table 4.

Quaternary	Pedagogical approach			
Tertiary	Course design			
Secondary	Course design components			
Primary	Own material	External material	Repurposed external material	Reification of practice

Table 4: The tentative taxonomy of reuse

I do not assert that this is a taxonomy in a strong sense, in the meaning within a “covering law model” of scientific knowledge, where taxonomies are classification of stable phenomena that are instances of law-like generalities. It is rather a classification scheme that can help systemize emerging theoretical conceptions of learning resource reuse. As such, the taxonomy can be regarded as an intermediate concept. Intermediate concepts are between theories or theoretical principles and empirical data. They are means for reciprocally making sense of field research and making sense of theoretical concepts, and “intermediate concept construction contributes to the basis for generalization from particularized qualitative case examples.” (Gregory, 2000, p. 5). The tentative taxonomy is based on two specific, situated learning situations. Clearly, studies from a wide variety of learning situations are required in order to develop a comprehensive understanding of learning resource reuse.

Our designation of the four levels of reuse coincides with the four levels of contradictions in Engeström’s model of activity. I do not imply that there is a correlation between the levels of reuse and the levels of contradictions. The naming is meant to be a generic labeling of a four-tiered structure.



### *The taxonomy of reuse and learning technology standards*

In Paper V, we also discuss how learning technology standards relate to the four levels of reuse in our taxonomy. The primary level categorizes learning materials, which constitute the focus of SCORM. They are treated as learning objects, described with metadata according to the IEEE LOM standard. I am not aware of any standards or specifications that are explicitly concerned with secondary level reuse. However, they can be part of an IMS LD unit of learning, and be extracted for use in another context. Tertiary level reuse is the explicit area of concern for IMS LD. For the special case of one individual learner working exclusively with ICT-based learning material, tertiary level reuse is also accommodated by SCORM. In the field of CSCL, CSCL scripts might be used, even though there is not an established standard for how these should be specified. Reuse at the quaternary level is to some extent supported by the large body of literature on pedagogy, but these descriptions are not formulated in a formal language. In summary, learning technology standards and specifications are mostly concerned with reuse at the primary and tertiary level, and do not explicitly address the secondary and quaternary levels.

At a more detailed level, my research offers insights into the kinds of learning resource reuse described at the primary level of the taxonomy. The primary level builds on the categorization proposed by Koper (2003), where reuse is differentiated with respect to the relation of the resource creator to the context in which the resources are used. In the discussion of the taxonomy in Paper V, recommendations with respect to standards deployment for the four categories of primary level reuse are offered. We suggested that transformation of a teacher's own material into learning objects is of limited value. We cannot expect repurposed external material to be designed as learning objects, but it might be beneficial to create learning objects that reference such resources. We indicated that resources in category 2, external material, are likely candidates for being transformed into learning objects. Category 4 resources, reification of practice, might benefit from being furnished with metadata. As the scope of their use is more local, we did not find strong indications that would suggest benefits from metadata tagging of these according to the IEEE LOM standard.

Further, we found that some primary level resources (assignments, exercises) were regularly reused, while other such resources were reused more sparsely (examples, videos). Our data suggested that the teachers reusing assignments and exercises considered to important to carefully design and precisely describe these resources, and that they were often subject

to refinement over time. Examples, on the other hand, could be more loosely described because they could be contextualized and elaborated upon when they were presented by the teacher. Use of both examples and pre-produced videos seemed to be more sensitive to the teacher's personal style and preferences than those resources that were reused. This finding can indicate that there is also a need to differentiate primary level resources within the same category with respect to standards deployment.

### *Conclusions on R-III*

The third research question addresses the issue of how learning resources are reused in educational institutions, and what kinds of resources that are reused.

The main findings are systematized in the taxonomy of reuse. The taxonomy categorizes resources along two dimensions. In the first, reusable learning resources are categorized according to the content creators' relation to the context in which the resources are used. The other dimension differentiates learning resources with respect to four aggregation levels; primary through quaternary level reuse. Primary level reuse is addressed by SCORM, and tertiary level reuse is the explicit area of concern for IMS LD. Learning technology specifications do not explicitly address the secondary and quaternary levels of reuse. At a more detailed level, the analysis suggests that two types of primary level resources are candidates for being furnished with metadata – “external material” and “reification of practice”. Further, some primary level resources were reused to a larger extent than others.

## 5.4 Implications

This section discusses the implications of my research findings for the two areas of study that my research addresses: learning technology standardization and CSCL.

The central research object in my PhD project is reuse of learning resources, in learning situations taking place within educational institutions. Findings from these inquiries inform the field of learning technology standardization. The major contribution is concerned with deployment of specifications and standards for learning technologies, but the research is also of interest for design of such standards. The contributions to this field are summarized in Section 5.4.1.

A major part of the research has been carried out on ICT-mediated learning environments, where facilitation for student collaboration has been central in the design of these environments. Such environments are of central interest in the research field of Computer Sup-

ported Collaborative Learning. The contributions of my research to CSCL are presented in Section 5.4.2. This section also includes reflections on how my use of cultural-historical activity theory contributes to the development of the CSCL field.

### 5.4.1 Standardization

The most important contribution from my research to the field of learning technology standardization is to direct attention to the issue of understanding how learning resources are reused in educational contexts. Reuse is of major importance for the field, since it is at the core of the rationale for standardizing learning resources. This thesis contributes to two aspects of standardization: First, it offers findings of interest to deployment of standards and specifications; and secondly, findings that might inform design of specifications for learning technology.

#### *Standards deployment*

The concept of reuse is underdeveloped in discussions on learning technology standardization (Doorten, Giesbers, Janssen, Daniels, & Koper, 2003; Koper, 2003). My findings on reuse in CSCL settings are synthesized in the taxonomy proposed in Paper V. The primary application area of this framework is in deployment of learning technology standards and specifications. It can be used by content creators and course designers as support for making decisions about if and how to make use of the specifications. The taxonomy can be used for deliberations on what kind of resources should be designed according to the specifications, as well as for defining requirements for ICT-based tools to be used in the learning situations. The taxonomy is also of potential benefit for policy-makers, both at an institutional and cross-institutional level. For example, should standards compliance be a condition for receiving funding for development of digital learning resources within a particular program? Paper V also discusses how central standards and specifications address the various levels of reuse in the taxonomy. This, together with the descriptions and analyses of these specifications in Chapter 3 and Paper I, can assist decision-makers when choosing an approach to deployment of learning technology standards and specifications.

The question of how central learning technology standards and specifications accommodate pedagogical approaches found in educational institutions is of central interest for considerations of deployment of these in such institutions. Problematic aspects related to deployment of SCORM within an instructional context that emphasizes the social nature of

learning has been recognized for some time (Friesen, 2004b; Hoel, 2003; Koper & Olivier, 2004; Welsch, 2002; Wiley, 2003). However, this critique of SCORM has largely been carried out at an ontological level. SCORM has its roots in requirements of training in the US military and large engineering corporations. The prevailing ‘positivistic’ view on learning in these institutions is directly in opposition to the values and interests in educational institutions. Therefore, the argument goes, SCORM is of limited value in this context. In Paper I, we go beyond abstract discussions on how e-learning standards relate to various pedagogical approaches. Our findings, summarized in Section 5.1, are more specific and they can help in making informed choices with regard to deployment of SCORM. I have also discussed the IMS Learning Design specification with regard to standards deployment. Our findings indicate that inquiry-based science projects can be fully described within this specification. However, the IMS LD is a recent development and not yet widely supported by learning technologies. A related issue is that IMS LD is a complex specification, and it requires a substantial supporting framework of components and services in order to have impact on educational practice. Such supports are still under development.

An IMS learning design, a CSCL script, or a collection of learning objects structured in a SCORM content organization can all be regarded as a plan for how the students are to carry out a learning process. A plan can be understood as the formulation of a sequence of purposeful actions which leads to a preconceived end, providing instructions that guide some actor’s path from the initial state to the goal state. As I see it, this understanding of plans is reflected in SCORM. But when dealing with open-ended and ill-structured problems, it is neither possible nor desirable to prescribe the students’ course of action in detail in advance. Suchman (1987) argues that every course of action depends in essential ways upon its material and social circumstances. “As ways of talking about action, plans as such neither determine the actual course of situated action nor adequately reconstruct it.” (Ibid., p. 3). Plans should rather be conceptualized as resources for practical deliberations about action. When considering deployment of learning technology standards, the issue of how these accommodate the learners’ situated actions is of importance.

My understanding of SCORM is that it represents a structure for providing a prescribed set of instructions, with few opportunities to make adjustments to the plan as the learning activity unfolds. The SCORM Sequencing and Navigation specification makes it possible to dynamically adjust a user’s path through learning objects at run-time, but such customization is limited to preconceived alternatives at design-time. With the mechanisms

in levels B and C, IMS LD seems to be more promising with respect to flexibility at run-time. However, as there are still relatively few implementations of IMS learning designs, it is too early to conclude on this specification's capability for handling students' situated actions.

### *Standards design*

My research can contribute to design of specifications in two ways. The reuse taxonomy identifies two areas of concern that are not explicitly addressed by specifications; secondary and quaternary level reuse. The taxonomy offers an opportunity to reflect on how well the current specifications cover reuse practices. The findings might indicate that specification at these levels is not feasible or needed, but it could also mean that there is potential for further development of the specifications. There might be practices with regard to reuse that are not supported by standards, practices that could benefit from such support.

The other contribution to specification design is the findings on how learning resources are reused. Such insights can help reduce the complexity of some of the specifications, especially those concerned with metadata. For example, a well-known problem with IEEE LOM is the large number of metadata elements (e.g., Friesen, Hesemeier, & Roberts, 2004). One approach taken in the standardization community to address this is to study usage of metadata elements in learning object repositories (Friesen, 2004a; Friesen & Nirhamo, 2003). My approach is to study situated usage of learning resources. My findings indicate that some kinds of resources might be more disposed for reuse than others. By accumulating empirical knowledge on reuse, some kinds of resources might be identified as of marginal interest. Any metadata elements – or items in controlled vocabularies – that are pertinent for only these kinds can then be removed. This can be done either by modification of the IEEE LOM standard, or by creating an application profile of it.

There are few, if any, indications of influence from CSCL research on the SCORM framework. IMS LD, on the other hand, is founded on studies of more than a hundred different pedagogical approaches, including many collaborative learning approaches (Koper, 2001). CSCL is a field of research where the reciprocal relationship between various technologies and learning is central, a position that should be well aligned with the concerns of the learning technology standardization community. The wealth of knowledge currently being developed by the CSCL community provides opportunities for specification developers to gain new insights on their problem domain.

## 5.4.2 CSCL

The most important implications of my research for CSCL are related to learning technology standardization, findings on the role of shared events in a distributed CSCL environment, and my application of the analytical framework of cultural-historical activity theory.

### *CSCL and standardization*

CSCL systems are often developed to explore ideas about learning or new technological opportunities, and there are many experimental systems described in CSCL literature. Although CSCL research has brought forth some production-scale systems (for example, WISE), the emphasis is clearly on prototypes and pilot systems not intended for long-term use in educational practice. With this background, it is not surprising that issues pertaining to sustainable deployment of CSCL systems in educational institutions receive modest attention in the CSCL research community. These issues include how new technologies can be implemented in existing technological infrastructure, the scalability and robustness of the systems, interoperability with other systems, and how they can be taken in use by students, faculty, and administrative staff. As the CSCL field matures, I believe that some of the many innovative systems from the field will be brought into educational institutions and will help shape everyday practice in these institutions. This argument is in accordance with a recent call for CSCL to also focus on meso-level activity (Jones, Dirckinck-Holmfeld, & Lindström, 2006). The meso level is here understood as an intermediate level between small-scale local interaction and large-scale policy and institutional processes, and it includes a focus on “how the technology and infrastructure affords, and mediates the learning taking place.” (Ibid, p. 37). As part of this development, the concerns addressed by the standardization field will become more relevant for CSCL.

Today, culturally developed insights on how students’ collaborative learning activities can be supported and structured are reified within the CSCL systems. That is, they are in many ways inseparable from the systems themselves, being built into the systems. One example of this can be found in the FLE2 system, designed to support collaborative knowledge building and progressive inquiry (Leinonen, Virtanen, Hakkarainen, & Kligyte, 2002). Part of this system is the knowledge building forum, where the students are prompted to assign a built-in category (for example “problem” or “my working theory”) to their postings on the discussion board (Ludvigsen & Mørch, 2003). This tool, which is an implementation of a clear idea about learning, is an integrated component of the FLE2 system. While it is evi-

dent, from a sociocultural perspective, that artifacts such as FLE2 are carriers of culturally developed knowledge, such reifications can be more or less firmly bound to the CSCL systems. SCORM structures of learning objects, IMS learning designs, CSCL scripts, and pedagogical agents are examples of mechanisms that facilitate a looser binding between reified knowledge and specific CSCL systems. The discussion in Section 3.1 indicates that standards represent an opportunity that can help implementation of sustainable CSCL environments, where learning resources of high quality and ‘best practices’ can be shared. The literature review presented in Section 3.3 shows a modest but growing interest in standards and specifications for learning technology in CSCL. This interest is currently strongest in formalized collaboration scripts and the IMS Learning Design specification.

One ambition of my research is to help raise awareness of possibilities and constraints of standardization within the research field of CSCL. In Paper I, we discuss SCORM and IMS LD with respect to the WISE CSCL system and design of the SAIL CSCL framework, and provide specific findings on how these can be applied productively in specifications for such CSCL systems. The empirical study presented in Paper IV represents a different take on standardization. Here, we study the roles of the online meetings in the overall learning situation. We conclude that a transformation of these shared events into reusable learning objects could disrupt the students’ learning processes. We argue that a thorough understanding of the systemic relations of the components in the learning situation is of central importance when considering redesign of learning resources for standardization purposes.

### *Unit of analysis*

Many studies of distributed CSCL involve analyses of how social interactions contribute to collaborative knowledge building on the subject domain (e.g., de Jong, Veldhuis-Diermanse, & Lutgens, 2002; Dennen & Paulus, 2005). Our analysis in Paper IV concludes that the students regarded the online meetings as important. However, it indicates that the interactions regarding object-orientation did not by themselves account for the students’ appreciation of the meetings. Rather, we propose that participation in the shared events had a less direct value for the students<sup>31</sup>. This might be an issue of importance for design of distributed CSCL systems. Even though analyses of interactions in synchronous communication forums show little evidence of collaborative knowledge construction on

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<sup>31</sup> Thanks to Yrjö Engeström for bringing this issue to our attention.

the subject domain, such forums might still be valuable for the students. Their significance might be that they facilitate processes that serve as anchoring for social learning processes, in that they contribute to creating premises for productive learning processes.

I suspect that characteristics of the student cohort were important for understanding why discussions on the subject matter were modest during the meetings. The IOOP 03 students were adults and most held full-time jobs – several as programmers. In our interviews with the students, many stated that they discussed specific problems they encountered in the assignments with colleagues from their workplace or friends with knowledge of object-orientation. That is, they drew on resources from personal relations outside the student peer group for discussing object-orientation. This can contribute to an account for the modest dialogue on the subject matter.

The IOOP 04 students represent an interesting contrast in this respect. The majority of these students were enrolled in a Masters program in multimedia design, and not in the software construction program the IOOP 03 students took part in. Most IOOP 04 students did not expect to code Java programs in their future work, but rather took the course to gain insights on how programmers work. These students engaged in collective discussions on the subject matter to a larger extent than the IOOP 03 students. These discussions were often organized by the peer work groups, and carried out by the help of the IM application. The IOOP 04 students I interviewed did not engage people outside the IOOP context in discussions on object-orientation to the same extent as the IOOP 03 students, according to their own accounts. My impression is that the IOOP 04 students did not have access to a professional community to the same degree as the IOOP 03 students, and that they therefore relied more on their peer students for discussing the assignments.

Following from this, I suggest that awareness of who the students are and their motives for participating in a particular course can be of importance when designing ICT-mediated learning environments for distributed CSCL settings. This position is supported by Fjuk and Ludvigsen (2001). When viewing students' collaboration in an activity system, the authors argue, it is important to understand how that activity system is related to other activity system the students participate in. The IOOP cases indicate that characteristics of the student group, in terms of access to resources for understanding the subject matter outside the formal learning activity system, can have implications for what kind of mechanisms for social interaction that should be provided for them.



## *CHAT*

I have used cultural-historical activity theory (CHAT) as my analytical framework in all the studies reported in this thesis. It is not the ambition of this thesis to contribute new theoretical knowledge *pre se* to CHAT. However, given the current non-dogmatic nature of CHAT research (Engeström & Miettinen, 1999), my work does inform this framework with respect to how it is applied in the studies reported here. The most common type of CSCL research using CHAT is intervention studies (e.g., Guribye, Andreassen, & Wasson, 2003; Kränge & Fjuk, 2004). The major body of my research is based on non-intervention studies. Although this approach is not that common, there are examples of such types of studies in CSCL (Chernobilsky, Nagarajan, & Hmelo-Silver, 2005; Hedestig & Kaptelinin, 2005). While this is not a novel approach to analyzing CSCL environments, my PhD research as a whole provides exemplars of how such studies can be carried out.

Papers III and IV present research that was conducted by non-intervention studies of relatively short duration (five months). These papers show how the CHAT analytical framework can be used to identify problematic aspects of learning situations by looking for areas of tensions in the activity system. A similar approach was used in Paper I, where we searched for tensions between the affordances and constraints given by learning technology specifications and the requirements of technology support for science inquiry projects. The multi-level analysis in Paper IV demonstrates how CHAT can be used for understanding the roles of one particular artifact, in the context of the whole course design. This paper also provides an example of the object of activity as a potent analytical means. It is only after suggesting “the creation and maintenance of their community of practice” as the object of the participants’ activity that we are able to provide an account for their actions during the online meetings.

Paper III also shows how the CHAT analysis resulted in the identification of issues that were subsequently addressed in a short-term intervention study. This is an example of how analysis of an ICT-mediated learning environment using CHAT results in findings that are generalized in the form of design proposals. The assumptions behind these proposals can then be tested by implementing them and subjecting the use of the redesigned environment to new analyses. This iterative mode of learning environment development is a common approach to systems development in CSCL. The concept of contradictions is an important analytical instrument in CHAT, and emphasis that entails an orientation towards change

and development. I therefore regard CHAT as a compelling analytical framework for iterative development of CSCL systems.

In summary, I contend that my application of CHAT adds to the body of research that CSCL researchers and system designers can draw from in their efforts to refine or create new ICT-based learning environments.

## 5.5 Summary of research findings

The central aim of my research has been to develop a conception of reuse that facilitates systematic analysis of learning resource reuse in ICT-mediated collaborative learning environments. I contend that reuse constitutes a core argument for the development of learning technology standards and specifications, and I have shown that the phenomenon of reuse is both empirically and theoretically underdeveloped in the field of learning technology standardization. The findings from my empirical studies of reuse are systematized in a tentative taxonomy of reuse, presented in Table 4 on page 80.

The most important contribution of my research is that it brings the issue of how learning resources are reused in educational institutions into the foreground. My conception of reuse informs research concerned with both learning technology standardization and CSCL.

The taxonomy of reuse can be used in deliberations on standards deployment in educational institutions. It can help guide decisions on which learning resources to design according to standards, and the findings on how SCORM and IMS LD accommodate collaborative learning approaches can assist decision-makers in choosing appropriate mechanisms for facilitating reuse of learning resources. For the design of learning technology standards, the taxonomy offers an opportunity to think about how well the standards reflect reuse practice. The findings on how learning resources are reused can also be used for redesigning standards with respect to reducing complexity.

My conception of reuse has enabled me to develop a discussion on standardization in CSCL research. I have argued that standardization will become more relevant for CSCL research as experimental CSCL systems are brought into educational institutions and help shape the everyday practice in these institutions. Learning technology standards represent an opportunity for the CSCL research community to reify findings on productive collaborative interactions, and for implementing sustainable CSCL systems in educational institutions. But my research has also identified challenges in converting learning resources

into reusable learning objects. I have shown that it is crucial to be aware of the various roles of learning resources in the totality of the students' learning activity when considering redesign with respect to facilitation for reuse. These include roles that might not have been anticipated in the course design.



# 6 Conclusions and Further Research

The main conclusions on my research questions are summarized in this chapter, and possible directions for further research are discussed.

## 6.1 Conclusions

The central aim of my research has been to develop a conception of reuse that facilitates systematic analysis of learning resource reuse in ICT-mediated collaborative learning environments. This aim has been approached by addressing three research questions. Conclusions on these research questions are provided below.

The first research question raises the issue of how learning technology standards accommodate pedagogical approaches found in educational institutions. The two specifications SCORM and IMS LD were analyzed in the SAIL case study. My research adds findings based on empirical studies to the theoretically based concerns regarding SCORM in relation to collaborative learning. The IEEE LOM standard, which is part of the SCORM framework, was found to be applicable in technology support for collaborative learning. But when collections of de-contextualized learning objects were aggregated into larger units, tensions appeared between the design team's requirements and the specifications collected in SCORM. The analysis also showed that while inquiry-based science projects can be fully described within IMS LD, the descriptive approach taken in this specification leaves many detailed issues unspecified.

The second research question is concerned with the roles of digital learning resources in ICT-mediated learning environments. The analyses of the IOOP case studies pertinent to this research question focus on the shared events constituted by the online meetings. A central finding was that these meetings had the role of mediating the students' actions towards the creation and maintenance of a community of practice on object-oriented programming. This was a role not anticipated in the course design. Furthermore, a transformation of the meetings into reusable learning objects might maintain their function with respect to the subject domain, but would disrupt social processes that contribute to creating premises for productive learning processes. The IOOP 04 design experiment also provided insight into the second research question. Three patterns of social interaction were identified, and the analysis suggested that these were influenced by the students' pre-

prepared solutions to the problem they were given. We proposed that these student-generated artifacts, along with how these were presented, contributed to shaping the groups' collective activity.

The third research question addresses the issues of how learning resources are reused in educational institutions, and what kinds of resources are reused. The main findings regarding this research question are systematized in the taxonomy of reuse. Based on empirical material from the IOOP studies, the taxonomy categorizes resources along two dimensions. In the first, reusable learning resources are categorized according to the content creators' relation to the context in which the resources are used. The other dimension differentiates learning resources with respect to four aggregation levels: primary through quaternary level reuse. Primary level reuse is addressed by SCORM, and tertiary level reuse is the explicit area of concern for IMS LD. Learning technology specifications do not explicitly address the secondary and quaternary levels of reuse. At a more detailed level, the analysis suggests that two types of primary level resources are candidates for being furnished with metadata – “external material” and “reification of practice”. Further, some primary level resources (assignments, exercises) were reused to a larger extent than others (examples, videos).

At a more overall level, the intermediate concept of reuse developed in this thesis informs the two research areas CSCL and learning technology standardization. It serves as a mechanism for discussing the issue of scalability of CSCL systems, and provides empirically informed perspectives on reuse to the learning technology standardization community.

My research has indicated that it is feasible (and often desirable) to describe small units of digital learning content according to standards. These learning objects are provided to students as resources they can use in their learning processes. But when the learning objects are aggregated into larger units, standardization will to a greater extent become an issue of prescribing students' actions. This represents a challenge in relation to pedagogical approaches emphasizing the social and dynamic nature of learning processes. I see this as a fundamental tension between providing support for students' learning processes by structuring their actions and granting sufficient flexibility for productive collaborative learning processes to develop. A better understanding of this tension is important for moving forward the discussion on opportunities and constraints represented by learning

technology standardization for CSCL. In the next section, I suggest how further development of my conception of reuse can help address this issue.

## 6.2 Further research

This thesis directs attention towards the phenomenon of *reuse* as relevant for the fields of learning technology standardization and Computer Supported Collaborative Learning. The main device for creating awareness of the multifaceted practice of reuse is the taxonomy of reuse. As indicated in the previous section, the taxonomy might be developed into an artifact that can aid analysis of the tension between providing structure and allowing flexibility in CSCL systems. I propose various approaches to such a development in Section 6.2.1 below. In Section 6.2.2, two other areas of interest for further research are discussed: empirical studies of IMS Learning Design and further inquires into the situated conditions for learning in ICT-mediated learning activities.

### 6.2.1 Development of the taxonomy

The taxonomy of reuse (restated in Table 5 on page 96) is tentative. It is based on empirical research conducted on a small number of case studies of specific learning situations. The taxonomy should be applied in empirical research on a larger number of learning situations, in diverse contexts and subject domains. Such research will probably refine the taxonomy, providing additional detail on the four levels of reuse and maybe add new levels.

In addition to broadening the empirical basis for the taxonomy as suggested above, one promising approach to such a development is to strengthen the theoretical basis for the taxonomy. The horizontal axis of the taxonomy differentiates reuse according to the content creators' relation to the context in which the resources are used. The vertical axis can be seen as aggregation levels, similar to the structure in the SCORM Content Aggregation Model (Section 3.1.3). This classification scheme is also consistent with how aggregation is understood in object-oriented programming. In this perspective, the three lower levels on the vertical axis reflect a hierarchical classification structure, where the levels form a whole-part aggregation composition. A learning resource at the primary level is a part of a course design component at the secondary level. This component, in turn, is part of a course design, which is found on the tertiary level. A specific course design can be regarded as an instance of a quaternary-level pedagogical approach.

Quaternary	Pedagogical approach			
Tertiary	Course design			
Secondary	Course design components			
Primary	Own material	External material	Repurposed external material	Reification of practice

Table 5: The taxonomy of reuse

This conceptualization of the vertical axis, however, does little to help the understanding of how reuse at the various levels might affect the structuring of learning processes. In the following, I first explore the relation between the taxonomy and Leontiev’s structure of activity, and then discuss the taxonomy in relation to Engeström’s model of activity.

In addition to considering levels of aggregation along the vertical axis of the taxonomy, it might be beneficial to reflect on the four levels of reuse in terms of Leontiev’s structure of activity. This understanding of activity, discussed in Section 2.2, is commonly visualized as shown in Figure 7. Activities are analytically identified by the motive that elicits them, and they are collective formations that are carried out by *a community*. Activities are realized through goal-directed actions, carried out by *individuals or teams*. Actions consist of chains of operations, which are performed routinely by *individuals* under given conditions. The vertical arrows in the figure indicate the dynamic nature of the model, as processes can move between levels.

There is a gradual shift from the individual to the collective in Leontiev’s structure of activity, moving from individual operations, through individuals or groups’ actions, to collective activity. A similar line might be read into the taxonomy of reuse. Learning objects at the primary level can be used by individuals, and reuse at the secondary and tertiary levels has more impact on collaborative processes. I do not propose a one-to-one relationship between Leontiev’s structure of activity and the three lower levels of the taxonomy of reuse, but the correspondence between them with regard to individual – collective dimension might be used productively to develop the taxonomy.



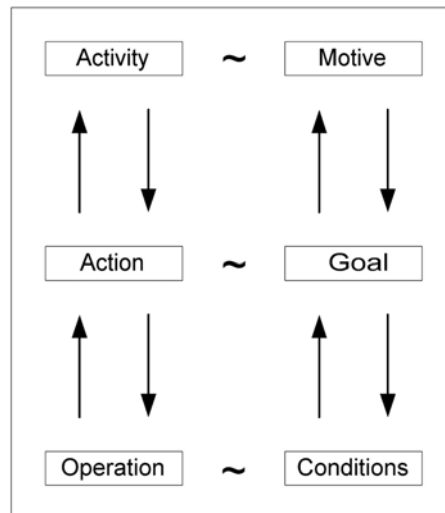


Figure 7: The structure of activity<sup>32</sup>

Another approach to strengthening the theoretical foundation of the taxonomy, which might be complementary to the one described above, is to relate it to Engeström’s model of activity. I propose that it might be beneficial to follow the position of a learning resource in various activity systems through its development. Analysis of such a trajectory can inform the impact of reuse of the resource on students’ collaborative learning processes. In the following, I explore this idea through an example. The sketches of activity systems I use in this example are not fully worked out; only the key components illustrating the idea are indicated.

The example outlines the development of a learning design which complies with the IMS LD specification, but development of other learning resources such as a collaboration script or a learning object could have been used. Figure 8 shows the activity of creating a learning design for introductory object-oriented programming (OOP). The learning design is called “objects-first”. The object of the activity is the script, where the perceived outcome can be the provision of cost-effective courses on object-oriented programming of high quality for the three universities involved in the development. The subject in the activity systems is the group of developers, including subject domain experts, technology developers, experts in informatics didactics, etc. Important tools for developing the script include the IMS LD specification, the CopperCore LD engine, a Learning Design editor and various teaching materials. The pedagogical approach guiding the development, for example inquiry-based learning, is located in the rules component of the activity system. In

<sup>32</sup> The figure is adapted from Kuutti (1996).

relation to the taxonomy, primary and secondary level resources are located in the tools component, the tertiary level resource is the object of the activity, and quaternary resources are located in the rules component.

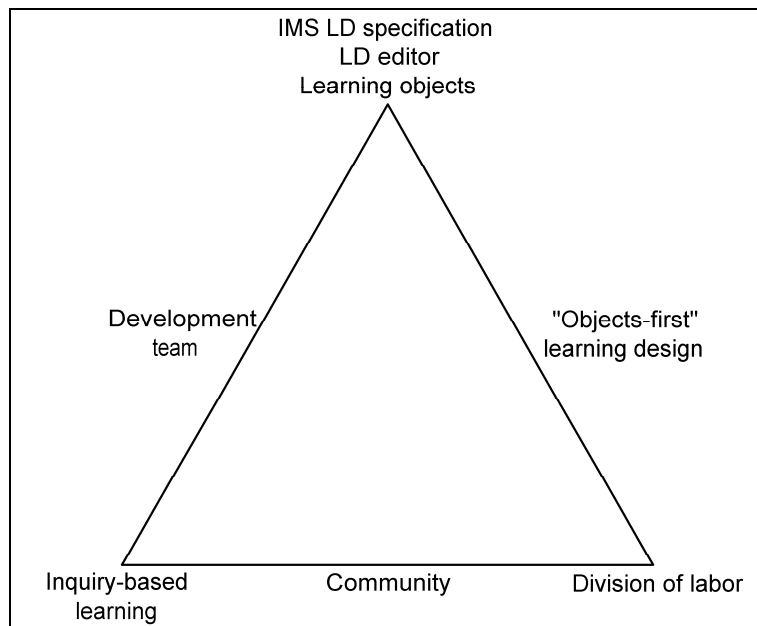


Figure 8: Learning design development

The learning design resulting from this activity is a collection of scripts specifying, for example, 15 units of learning (lessons). Various roles are specified along with the actions to be performed by the people occupying these roles, as well as what learning content and which tools are to be used.

A next phase can be the activity of two teachers in one of the collaborating universities planning next semester's course on OOP. They use the objects-first learning design in this work, and the expected outcome of the process is a plan for course. Part of the preparation involves actions such as assigning people to roles, populating student groups, specifying which IM application and programming environment to use, and replacing some of the examples suggested in the learning design with material created by one of the teacher. The object of this activity is the preparation of a particular instance of a course on OOP, for example OOP-06. The subject in this activity is the two teachers, and the learning design objects-first is located in the tools component. Institutional norms and rules are included in the rules component. Resources in the three lower levels of the taxonomy are located in the tools component in this activity system, which is illustrated in Figure 9.

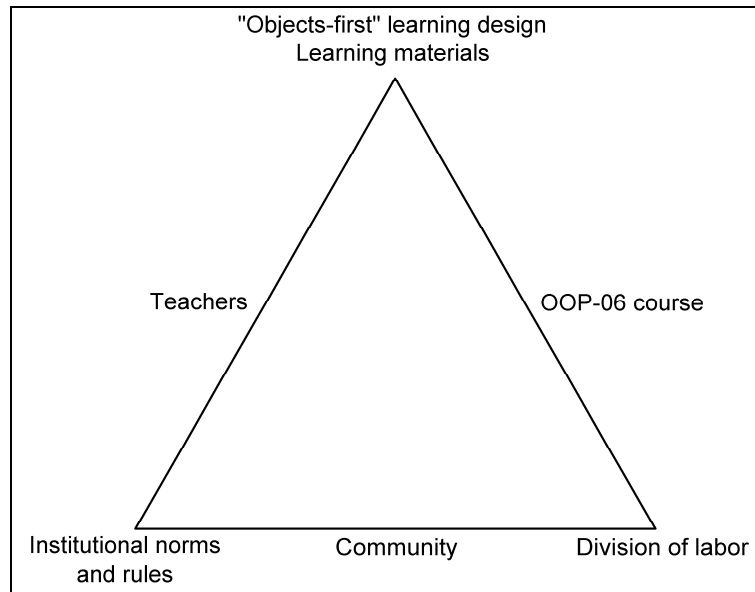


Figure 9: Learning design deployment

The third phase I discuss in this example is the progress of the course during the semester. If we focus on the students as they engage in their learning processes, they become positioned in the subject component of the activity system shown in Figure 10. The object of this activity can be OOP concepts and programming techniques, and the perceived outcome can be qualification for further studies in computer science. The learning resources they use, for example, assignments, textual descriptions, and a web-based discussion forum, are located in the tools component. The objects-first learning design determines when and how these artifacts are made available to the students. I therefore position the learning design in the rules component of this activity system. Primary and secondary level resources from the taxonomy are located in the tools component, the tertiary level resources is found in the rules component. The influence from quaternary level resources is more indirect in this activity system, as it is operationalized through the objects-first learning design.

This perspective might be especially beneficial for analyzing the important tension between providing structure and allowing flexibility, introduced in the previous section. The dynamics of the students' social processes might lead to actions that are not anticipated in the course design, as scripted in the objects-first learning design. The mediational artifacts at the students' disposal need to accommodate and support such unanticipated actions. If the learning design is too rigid, such dynamic processes might be impeded. Contradictions between these two components of the activity system might spin off new tool- or rule-producing activities.

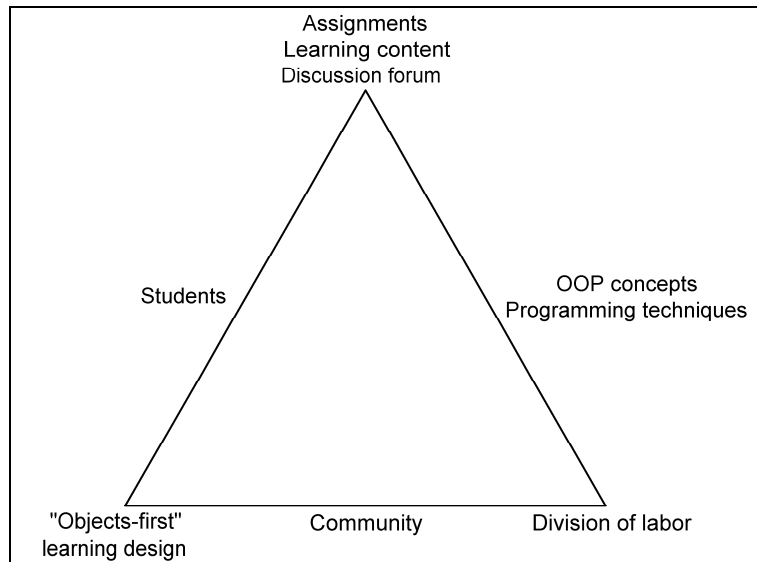


Figure 10: Learning design use

In this example, I have described the trajectory of a learning resource from development, through deployment, to use. This trajectory is illustrated in Figure 11. If experience from use of the learning design lead to redesign, the resource will yet again become the object of the activity and thus come full circle around the model of activity.

I have described how resources at different levels of reuse are positioned in the various activity systems described in the example. Integrating these perspectives into the taxonomy of reuse is a promising approach to further development of the taxonomy. A more thorough inquiry into how sociocultural understandings of activity can inform the taxonomy theoretically will contribute to the effort of creating a conception of reuse that can serve as an analytical tool in studies of design and use of CSCL systems.

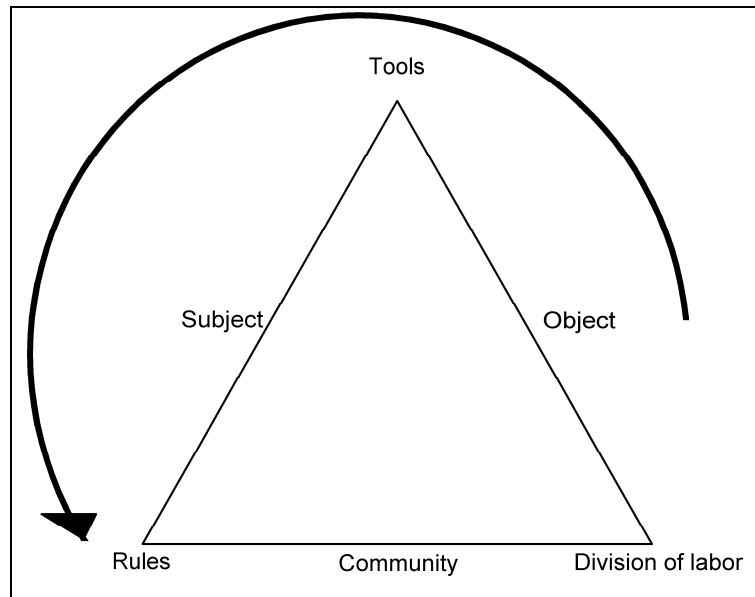


Figure 11: Trajectory of the learning design

## 6.2.2 IMS LD and new conditions for learning

In addition to development of the taxonomy of reuse, I suggest two other areas of interest for further research. These are concerned with IMS Learning Design and studies of the conditions for learning present in ICT-mediated learning situations.

Due to the complexity of IMS Learning Design, there is a need for a supporting framework of components and services if it is to have a substantial impact on learning technology. Such support is currently under development. When these are put into use, we will have a better empirical basis for evaluating the specification with respect to how it supports reuse in various learning situations.

In a historical perspective, the learning activities studied during this PhD project represent new conditions for learning. My research has explored the nature of some of these conditions in ICT-enhanced and -mediated learning situations, with a particular emphasis on the role of artifacts in learning environments. Furthermore, the research is concerned with how standardization might influence the internal systemic relations in and between the constituent components of activity systems in which learning takes place. A central tenet in sociocultural perspectives on human development is that actions are situated. It follows that knowledge of the new conditions for learning activity should be found in analyses of specific learning situations. My research findings are contributing to the accumulated knowledge within this field, and are part of an ongoing, collective effort in creating ICT-mediated learning environments that help facilitate productive learning processes.



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# Appendixes



# Appendix A

## Paper I

Berge, O. and Slotta, J. (forthcoming)

*Learning Technology Standards and Inquiry-Based Learning.*

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# Learning Technology Standards and Inquiry-Based Learning

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## Learning Objectives

- Characteristics of inquiry-based learning
- High-level requirements for technology support for inquiry-based learning
- Central features of the specifications SCORM and IMS Learning Design
- How SCORM and IMS LD accommodates inquiry-based learning science projects

## Executive Summary

The proliferation of technology-enhanced learning environments and digital learning resources in K12 and higher education has led to an interest in improving the cost-effectiveness of developing and deploying such materials within these institutions. The e-learning industry, which has been primarily concerned with training in corporations and the military, has approached this issue through the standardization of digital learning material in the form of learning objects. The Sharable Content Object Reference Model (SCORM) has emerged as the predominant approach to standardization among early adopters of learning object technology. While SCORM aims at being agnostic with respect to pedagogical approaches, there is some concern that SCORM-based learning objects are not well suited to all of the pedagogical approaches desired within formal educational contexts. An alternative specification that attempts to describe the use learning objects more broadly and with greater flexibility is that of the IMS Learning Design (LD).

We analyze the implications of the SCORM and LD specifications for the particular pedagogical domain of technology-enhanced inquiry learning. Our analysis builds on the extensive research conducted on technology supports for inquiry learning. We focus on a specific technology-enhanced inquiry science environment that has been designed through years of classroom-based research: The Web-based Inquiry Science Environment (WISE). Several important characteristics of the WISE pedagogical approach inform our discussion of learning objects and standards: Learning activities are carried out in a social or collaborative context within WISE; they occur primarily in a classroom setting; they are student-centered, and they are concerned with ill-structured problems. These characteristics are not unique to inquiry science projects, but rather represent an approach to pedagogy and curriculum design that is increasingly common across many domains within formal education.

The challenges of implementing SCORM within an instructional context that emphasizes the social nature of learning has been recognized for some time. However, this chapter contributes an analysis of how SCORM can accommodate the requirements of a specific pedagogical approach (inquiry-based science activities), including any particular elements of SCORM that are problematic for this approach. We will demonstrate that when de-contextualized learning resources are aggregated into larger units, tensions appear between the SCORM specification and the content designer's intentions. Several important issues are problematic, such as the ability to express collaborative activities, the tracking of students' activities within a group context, the support of teacher interventions, and the accommodation of students' un-anticipated use of learning resources. We also analyze the capability of IMS Learning Design to express the designer's instructional strategy together with the resources prepared for the learning situation. While our analysis reveals that inquiry-based science projects can be fully described within this specification, the descriptive approach taken in IMS LD leaves many detailed issues unspecified. For example, IMS LD does not set out to specify the mechanics of delivering a unit of learning. This means that the specification of requirements for any run-time environments (e.g., WISE) is to a large degree absent from LD. Thus, while LD offers sufficient scope and flexibility to capture the rich social or collaborative contexts of pedagogical approaches such as those employed by WISE, it currently lacks a sufficient level of specificity to be of great use to developers.

## Introduction

There has been an increased use of digital learning material in K-12 as well as higher education. This trend has led to a corresponding interest in improving the cost effectiveness of developing and deploying such materials within these institutions (e.g. Littlejohn, 2003; Friesen, 2004). In the e-learning industry, which has been primarily concerned with training in corporations and the military, this issue has been approached through standardization of digital learning material. In particular, the Sharable Content Object Reference Model (SCORM) has emerged as the predominant approach to standardization within the e-learning industry. While the SCORM aims at being agnostic with respect to pedagogical approaches (e.g. ADL, 2004b, p. 3-10), there exists some concern that SCORM-based content cannot respond well to certain pedagogical approaches—particularly those emphasizing social aspects of learning and inquiry-based learning. Another approach has been offered by the IMS Global Learning Consortium, in their Learning Design (LD) specification, which adopts a very broad description of learning, and promises to accommodate a wider range of learning materials, instructional settings and pedagogical approaches.

This chapter analyzes the implications of the SCORM and LD specifications for the particular pedagogical domain of technology-enhanced inquiry learning. Our analysis builds on the extensive research conducted on technology supports for inquiry learning, much of it conducted within the Computer Support for Collaborative Learning (CSCL) research community. We focus on a specific technology-enhanced inquiry science environment that has been designed through years of classroom-based research: The Web-based Inquiry Science Environment (WISE). Several important characteristics of the WISE pedagogical approach serve to illuminate our discussion of e-learning standards: Learning activities are carried out in a social context within WISE; they occur primarily in a classroom setting; they are student-centered, and they are concerned with ill-structured problems (e.g., design, debate, or critique activities). These characteristics are not unique to inquiry science projects, but rather represent a set of collaborative learning activities that are increasingly common within formal education. This chapter is relevant to the wider community of learning technology developers, who will be challenged by e-learning standards and speci-



fications in their effort to move technology-enhanced innovations into wider adoption within educational systems around the world.

This chapter goes beyond abstract discussions on how e-learning standards relate to various pedagogical approaches by analyzing how the standards can be applied productively within a specific pedagogical domain – that of inquiry learning. We summarize this perspective in the following, and proceed with a discussion of the high-level requirements for technology support that must be accommodated by the specifications of SCORM and LD. We also present a case study of how SCORM and LD were approached by the WISE technology developers, who are evaluating such e-learning standards as part of their design efforts. This case study includes a sociocultural analysis of the challenges confronted by the WISE design team as they attempted to incorporate SCORM and LD into the design of their next-generation technology-enhanced inquiry platform. This analysis sheds light on the challenges confronted by educational researchers as they attempt to incorporate these industry-oriented standards into new cutting edge systems that emphasize collaborative, inquiry-oriented pedagogies.

### ***Inquiry-Based Learning***

Inquiry-based learning is not a well-defined term, but the varying approaches to inquiry share some common beliefs. Based on Nickerson (1988) and Rubin (1996), we highlight the following characteristics of inquiry-based learning:

- Learning is an active process, rather than a passive assimilation of information. Students benefit from working on complex problems, which can be approached from many angles.
- Learning is enhanced by engaging in interaction with others working on the same problem, with language as the most important carrier of inquiry-related interactions.
- Conceptual understanding takes precedence over procedural efficiency. Knowledge about how to carry out a procedure is of limited value if the students do not have an understanding of how and when to use the procedure.
- Instruction must be sensitive to students' pre-existing knowledge of the phenomena under study. Some of a student's ideas might constitute a valuable base for learning, while others might be unproductive.
- Problems that are relevant to students' experiences outside of school enable them to make connections between what they learn outside of school and in class.
- Development of metacognitive skills enables students to take responsibility for managing and monitoring their own learning activities.
- Formal education should help to prepare students for lifelong learning by providing valuable problem solving and critiquing skills that will help them meet the demands of a rapidly changing society.

The particular approach to inquiry learning discussed here is based on a theoretical framework called "Scaffolded Knowledge Integration" developed by researchers at the University of California, Berkeley. (e.g., Linn & Songer, 1993; Linn & Hsi, 2000; Slotta & Linn, 2000; Linn, Eylon & Davis, 2004). In this framework, inquiry is understood as "engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, debating with peers, seeking information from experts, and

forming coherent arguments.” (Linn, Davis & Bell, 2004a, p. xvi). This framework guides the design of science inquiry curriculum where students “communicate about scientific concepts, evaluate scientific texts, conduct investigations, asks questions about science or technology policies, create designs, and critique arguments, often using technology resources.” (Linn, Davis & Bell, 2004b, p. 4). The knowledge integration perspective recognizes that students bring diverse ideas to science class – ideas that emerge from their interpretations of personal experience. Learners often hold multiple conflicting ideas about phenomena, which depend on the context in which the phenomenon is being considered. Effective inquiry science instruction enables students to make their web of ideas more robust and cohesive, evaluating their existing ideas, building connections among ideas, and promoting the most promising ideas. In this way, students develop their own scientific understandings.

The scaffolded knowledge integration framework contains four metaprinciples, each associated with a set of pragmatic pedagogical principles articulated by Linn and Hsi (2000). The first metaprinciple, which is to *make science accessible*, includes the pedagogical principles that instruction should build on student ideas; that the problems under study should be personally relevant for the students; and to scaffold inquiry by scaffolding science activities so students participate in diverse inquiry tasks and practice productive inquiry. The second metaprinciple, which is *to make thinking visible*, involves modeling and evaluating how ideas are connected and sorted out to form new knowledge webs. This includes practical pedagogical principles of modeling scientific thinking in student projects; scaffold students to make their thinking visible by explaining their ideas to teachers, peers, and experts; and providing multiple representations of the phenomenon under study. The metaprinciple, *help students learn from others* takes advantage of the collective knowledge of the classroom. This metaprinciple is operationalized by encouraging learners to listen to their peers; by designing discussions; by highlighting cultural norms; and by employing multiple social structures. Finally, the fourth metaprinciple, to *promote autonomy and lifelong learning*, encourages self-monitoring activities, and engages students as critics of diverse scientific information to help establish a perspective of lifelong learning.

It is interesting to reflect on the nature of learning content within such inquiry designs. Many educational technology researchers have developed materials that are consistent with an inquiry perspective (e.g., Roschelle, Pea, Hoadley, Gordon & Means, 2000; Schwartz, Brophy, Lin & Bransford, 1999). These researchers have developed inquiry science materials that engaged students with the use of real-time or prepared datasets (e.g., Reiser *et al.*, 2001; Edelson, 1999), online discussions with peers (Songer, 1996; Scardamalia & Bereiter, 1996); carefully structured classrooms as communities of learners (Brown & Campione, 1994), and scenario-based investigations (Bransford, Goldman & Vye, 1991) and collaborative investigations (deJong & van Jooligan, 1998). Many of these projects have used technology-based tools to scaffold students as they participated in such inquiry activities. The next section describes some of the high level principles of technology environments that are relevant to the discussion of learning content standards and specifications. Our discussion focuses on the WISE learning environment that was designed by researchers from the University of California, Berkeley in order to implement the Scaffolded Knowledge Integration framework and support a wide range of inquiry science learning materials.

### **Technology-Enhanced Inquiry Learning**

Researchers typically develop technology-enhanced tools or learning platforms in order to implement their ideas about inquiry learning. These platforms, sometimes called “learning

environments” provide a means of testing existing theoretical ideas and exploring new ones. In order to test and refine the Scaffolded Knowledge Integration framework, researchers at UC Berkeley have developed WISE, the Web-based Inquiry Science Environment (Slotta & Linn, 2000; Linn & Slotta, 2000; Slotta, 2002). WISE provides an Internet-based platform for middle and high school science activities where students work collaboratively on inquiry projects, making use of resources drawn from the Web. In one project, for example, students design a house for the desert climate by critiquing energy efficient house designs found on the Web, completing design worksheets, and discussing their design ideas online (Cuthbert & Slotta, 2004). In another project, students compare two competing theories about why deformed frogs are appearing in American waterways. Teachers select from a library of projects accompanied by lesson plans, assessments, scoring rubrics, connections to standards, and opportunities to customize the project to local issues and curriculum topics. Teachers can monitor and evaluate student work, provide feedback during a project, and manage student accounts. Over the past five years, the WISE technology and curriculum have been continuously revised, resulting in a library of more than 30 well-designed inquiry projects that have been used by more than 2000 science teachers and 100,000 students in 30 countries.

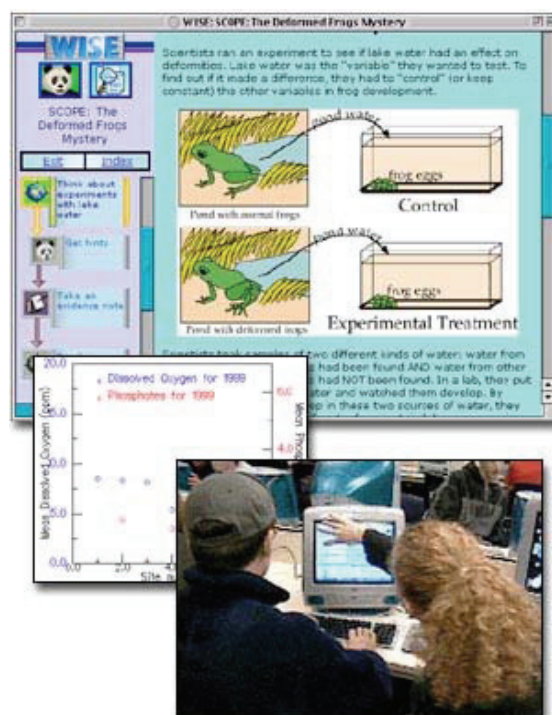


Figure 1: Students work collaboratively in WISE projects, supported by open-ended inquiry tools that scaffold their efforts in design, debate, or critique activities.

The scaffolded knowledge integration framework emphasizes learning activities that occur in the context of a classroom or computer lab, where students and teachers interact with each other concerning the ideas presented in the technology-enhanced lesson. WISE learning activities are organized as inquiry science projects, with duration of approximately one week (five 45-minute sessions). The projects are carried out in small groups of two or three to five students who work together on a single computer. Ideally, students interact with each other and with the teacher regarding their ideas about the science content, using the WISE technology to mediate their interactions (e.g., by pointing to the screen, where

students have drawn a concept map using WISE, and the teacher notices an interesting relationship within the map). Technology environments like WISE should support students' collaborative activities carried out within project groups, as well as their individual activities, and should enable productive interactions between students, their peers and the teacher wherever possible. Another important aspect of this organization is that not all learning activities are carried out in the context of the computer-based application. In WISE, technology is used to scaffold many practices situated within the classroom, including online activities as well as offline labs, field trips, classroom debates, and worksheets. Thus, the ICT-based resources must accommodate such mixed-mode learning and teaching processes.

A feature that is common to WISE curriculum and to inquiry-based learning in general is the use of problems that are current within the public discourse, such as global warming, genetically modified foods, or policies regarding protection of wolves. These problems are not usually clear-cut, and are designed to foster more than factual knowledge on the topic: "Problem finding, as previously noted, is a part of virtually all real-world problem solving. Seldom except in school do problems come to us ready-made. Real-world problems are what Newell and Simon call 'ill-structured', which means that one does not know in advance or knows only vaguely what would constitute a solution. In the course of problem solving the goal itself takes shape. In many cases this means that the distinction between identifying a problem and solving it virtually disappears." (Bereiter & Scardamalia, 1993, p. 132). Such problems are ill-structured, requiring the integration of multiple sources of data to evaluate competing hypotheses or solutions (Suthers, 1998). This calls for open learning environments that provide access to resources and information that goes beyond the usual prepared learning material (e.g., by using original source materials, or external web sites). WISE has been designed to support such inquiry projects, including a wide range of learning tools and materials presented via the Web. The technology serves to present content, as well as to scaffold students and teachers as they use this content collaboratively in designing, debating or critiquing inquiry topics.

From a sociocultural perspective, learning involves responding to constraints and affordances of the instructional context, including material artifacts that are part of the learner's environment. WISE provides software scaffolds to help students gain expertise in using everyday resources such as newspapers, web search engines, reference works, or domain specific web sites in the context of inquiry projects. Such experiences help students develop competencies and skills that will be valuable to their learning within and outside of school settings. Moreover, project work on real-world, ill-structured problems builds on students' existing ideas and is likely to be perceived as relevant and connected to their everyday lives. However, the highly situated and open ended nature of such a pedagogy means that we can expect students to use learning resources in an un-anticipated manner, and to use material not even intended for use as instructional content. The role of the educational technology in such a curriculum is to facilitate the discovery of such resources, and to scaffold the students as they gain expertise in such learning processes. In describing the process of gaining expertise in writing, Bereiter and Scardamalia (1993) note: "Textbooks occasionally try to prescribe a best way to write for everyone, but this is foolish. The best way is a highly individual matter, and finding it means gaining important knowledge for expertise." (Ibid, p. 59)

As characterized above, technology-enhanced inquiry raises new challenges for assessment, as learning objectives go beyond the more traditional "text-book" knowledge pertaining to the problem domain. Inquiry instruction includes goals for less content-oriented learning gains in areas such as meta-cognition, collaboration, argumentation and discourse

skills, and the ability to evaluate relevance and validity of source materials. These goals have implications for assessment, which can include process-oriented data, such as recordings of the sequence of learner activities or tracking performance of complex tasks. WISE inquiry projects can include pre- and post assessments that challenge students to reflect and respond to complex problems. Other WISE assessments are embedded within the curriculum in the form of reflection notes, online discussions, drawings, casual maps, and graphically outlined scientific arguments (Slotta, 2004). The challenge for technology, then, is to capture student activities as the projects unfolds, as well as providing a rich set of mechanisms that enable students to convey their understanding within the subject domain as well as the important cognitive and metacognitive process goals.

As reflected by the scaffolded knowledge integration framework and the WISE learning environment, technology-enhanced inquiry learning can support students as they collaboratively engage in complex open-ended projects using diverse materials in unpredictable ways. Such systems must also support teachers as they track student progress and respond to questions in a classroom where numerous small groups of students engage in such curriculum. Such methods are very difficult to adopt (Slotta, 2004), as they require teachers to intertwine content, process, and metacognitive objectives. Technologies like the WISE learning environment can scaffold teachers and students by coordinating interactions and exchanges, providing guidance, and capturing data for purposes of assessment. Learning tools embedded within WISE can support diverse representations, models, and source material, as well as providing support for collaborative student activities. In general terms, WISE has been designed in such a way that the technology and inquiry curriculum help to capture the four metaprinciples of the scaffolded knowledge integration framework: to make science accessible, to make thinking visible, to help students learn from each other, and to promote autonomy and lifelong learning.

However, as the research has progressed, the developers of WISE have sought to expand their technology architecture and add a greater formalism to their treatment of curricular content, user communities, and user interaction data. These researchers have kept a close eye on the developments of e-learning within industry and higher education, and seek to extract any possible value from the emerging standards and specifications. Thus, as the WISE technology designers undertook the design of their next generation software, they began a systematic review and analysis of such resources. This effort is described below in a case study that captures the important tension between research-based innovations and the conventional pedagogical perspectives embodied within the existing e-learning community. It is imperative that e-learning standards be able to accommodate the innovative technology-enhanced methods and materials developed by researchers in order to promote their scaled adoption and to encourage the exchange and interoperability of resources.

## **Method**

The empirical part of the research presented in this chapter has been carried out as a case study of WISE, as one learning technology project that is making an effort to accommodate important e-learning concepts (e.g., semantic metadata, re-use of materials) as well as specifications like SCORM and IMS Learning Design. We analyze the design process of the WISE development team in terms of the challenges they confronted in applying SCORM and LD specifications to their inquiry-based collaborative pedagogy. The outcome of the WISE team's design process is a new hybrid specification for inquiry learning called SAIL (Scalable Architecture for Interactive Learning) that is designed to formalize e-learning content within CSCL systems and facilitate the reuse of learning resources. We performed a case study of the SAIL design process over a time span of 4 months, based on

analysis of design meetings, e-mail discussion lists, wiki (web-based co-authoring tool) discussions, review of design documents, and discussions with participants in the project group. The case study has been conducted by the first author during a sabbatical with the WISE design group. The second author is the WISE project director who is responsible for developing SAIL, and a member of the design team.

Recent research (e.g. Fjuk & Dirckinck-Holmfeld, 1997; Fjuk & Ludvigsen, 2001; Wasson & Ludvigsen, 2003; Furberg & Berge, 2003) shows that technology-enhanced learning environments represents a complex problem area, where the conditions for supporting effective learning processes can be found in an area of tensions between a variety of interconnected elements. These elements include the characteristics of the knowledge domain, the pedagogical approach, the learning resources, the constellation of mediating technologies, the target group of learners and instructors, and the organization of the learning activities. The sociocultural perspective on human development (Vygotsky, 1978, 1986; Leont'ev, 1978; Wertsch, 1991), with its emphasis on human activity as mediated by artifacts, is a helpful framework from which to understand the role of technology in such learning environments. Our analytical approach is inspired by Activity Theory (Engeström, 1987; Engeström, Miettinen & Punamäki, 1999). In particular, our analysis is guided by the concept of *contradictions*, which materialize as tensions or breakdowns in the activity systems under study. They can be found within the constituting elements of the activity system, between them, between the dominant form of the central activity and the object and motive of a culturally more advanced form of activity, and between the central activity and essential neighbor activities. The essence is to take in the systemic whole of the activity, based on the identified contradictions.

In this chapter, we analyze the activities of the WISE design team as they articulate a new architecture for learning objects called SAIL (Scalable Architecture for Interactive Learning). The objects of the study includes all participants within the design team, all artifacts (e.g., the WISE system, the SAIL specifications, SCORM, and LD), an external advisor (the first author) who offered expertise in learning technology specifications, the design goals (e.g., to implement the scaffolded knowledge integration pedagogy), and any constraints that might derive from the design goals or artifacts. Our approach for analyzing the learning technology specifications and standards in relation to the development of SAIL is to understand the activity of learning content development as activity systems, and look for contradictions, or tensions, in and between the elements of the activity. In particular, we identified tensions between learning technology specifications (SCORM and LD) and the design goals of the group pertaining to the implementation of inquiry pedagogies within the SAIL learning technology framework.

## **Case Study: Next Generation WISE and Standardization**

Like many innovations within the CSCL community, WISE began as a research-oriented platform, designed to test assertions about inquiry and technology, as discussed above. As WISE matured into a resource that science teachers increasingly relied upon (more than 2000 K-12 teachers now use WISE), the research team encountered new challenges relating to scalability of the core technologies, as well as the interoperability of WISE with other learning technologies. In response to these challenges, the WISE team began designing a new open source platform for learning technologies, called SAIL: Scalable Architecture for Interactive Learning, funded by the U.S. National Science Foundation (NSF). This new framework will enable a much greater level of reusability of learning content, a greater interoperability of learning objects, and the ability to distribute learning ma-

terials and user data over a wide network, rather than keeping it all stored on a central server.

The next generation learning environments that will replace WISE will be built according to the SAIL architecture, and will include a distributed network of local hosts that serve classrooms, schools and districts. While the central Web-server approach implemented by WISE offers many advantages, it is exciting to consider systems that utilize the full functionality of student computers (i.e., for more than just running the Web-browser), and benefit from the strength of locally hosted networks and peer-to-peer functionality. By establishing a new technology framework and open source paradigm, SAIL will promote an international community of developers who exchange learning technologies, customize one another's content, and continuously improve the framework itself.

An important goal of the design team (and thus one element of the activity system under consideration) was the desire to incorporate the latest developments in learning content management, including specifications like SCORM and LD, which the team members had learned about and wished to implement if possible. In addition to the possibility of adding a degree of credibility and standardization to the SAIL framework, the design team members had often encountered strong statements about the importance of being "SCORM compliant". Indeed, several ongoing collaborations had all but required that WISE become SCORM-compliant in order for the collaborations to continue. The team – consisting of educational researchers, staff programmers, and design specialists – had done its own research into SCORM, and were attracted to the notion of a highly specified model of digital content. If possible, it was decided that the SAIL architecture would embrace SCORM, and at the very least would adopt an explicit model for content that would contribute to a greater level of stability and interoperability.

A related project developed in Norwegian researchers is VITEN (<http://viten.no>). This project grew from collaborations between the WISE team and the Norwegian team, and began as a Norwegian version of WISE. Over time, VITEN has evolved into a learning environment that targets the specific features of the Norwegian system, and promotes the development of science inquiry curriculum. The VITEN developers see the specifications in SCORM as an opportunity for cultivating their aim of helping teachers improve their education. For example, a SCORM-based version of VITEN could enable the inquiry content to be more easily integrated with other learning technologies being developed for use in Norway. Several advantages can be obtained if the VITEN science projects could be imported into the Learning Management Systems used in Norwegian schools: The teachers and students can use a learning environment they are already familiar with; the teachers will have more freedom to modify the science projects, and VITEN can focus on curriculum development. VITEN is currently exploring this issue by converting one project, gene technology, for use in the learning environment *IT'S LEARNING* at 12 test sites. Preliminary findings from this study are reported in the section *The Sharable Content Object Reference Model*. One goal of the SAIL development effort is to enable the WISE and VITEN content to be more easily exchanged between these two research projects, and run more seamlessly within existing learning management systems.

In the next sections, we review the outcome of the SAIL design team's deliberations with regard to SCORM, as well as to Learning Design (LD), which is another specification framework that was discovered in the course of these deliberations. We present the main challenges of the technology and inquiry features, and the constraints and contradictions that illustrate pedagogical limitations of SCORM which eventually led to an incompatibility with the SAIL design.

## ***How Can SAIL Embrace Existing Learning Technology Standards?***

There are a wide range of initiatives working on standards and specifications for educational technology. These address issues such as learning content metadata and structuring, testing, content sequencing, learner information, learner portfolios, accessibility, competency definitions, digital rights management, learning design, e-learning infrastructure, and repository management and implementation. Because it was designing SAIL from the ground up, the design team wished to embrace these initiatives, benefit from their structure, and the wealth of effort that had gone into their formulation. The present chapter will focus on the evaluation of standards and specifications related to technology that supports the design, development, and use of digital learning resources for purposes of inquiry-based curriculum.

One key concept for standardization of learning content is *learning objects*. The fundamental idea behind learning objects is that instructional designers can build small (relative to the size of an entire course) instructional components that can be reused a number of times in different learning contexts (Wiley, 2000). Learning content is broken down to modules, where the content of the module is described with metadata. Adopting a standardized approach to the design of learning objects would offer SAIL the potential of achieving several benefits: modular learning objects could be re-used in different contexts, as well as within different Learning Management Systems, and could more easily be updated than large integrated blocks of content.

Within the worlds of corporate and military training, the SCORM is emerging as the predominant approach to standardization among early adopters of learning object technology (Edmonds & Barron, 2002). SCORM is a major body of work that has significantly impacted the standardization of educational technology, and it should be carefully considered by any project that is concerned with the sustainability of digital learning resources in the formal educational sector. However, there has been considerable discussion about the limitations of SCORM in terms of accommodating a breadth of pedagogical approaches (e.g. Hoel, 2003; Koper & Oliver, 2004; Welsch, 2002; Wiley, 2003). In a discussion on the origins of SCORM, Friesen (2001) argues that adoption of e-learning specifications into an formal educational context might be problematic: "The obvious fact is that the goals of public education, however they might be construed, are radically different than those of the American military" (ibid.). One central initiative that attempts to describe learning content more broadly and with greater flexibility is that of the IMS Learning Design (LD). Over the course of their deliberations about SCORM, the SAIL design team encountered several projects that had adopted LD precisely because of its wider applicability and more descriptive language for learning content as well as learning processes. Below, we review the design team's analysis of these two specifications, emphasizing tensions or constraints that occurred with respect to the pedagogical design goals of SAIL. It is hoped that this presentation will be of relevance to other learning technology projects that encounter the same challenge of adopting such specifications.

### ***The Sharable Content Object Reference Model***

The Sharable Content Object Reference Model (SCORM) is developed by the Advanced Distributed Learning Initiative (ADL), launched by the US Department of Defense and the US White House Office of Science and Technology Policy. SCORM is an important element in implementing ADL's vision, which is to "provide access to the highest quality education and training, tailored to individual needs, delivered cost-effectively anywhere and anytime" (ADL, n.d.). The primary motivation for the development of the SCORM is to



enhance learning while improving efficiency and reducing cost related to the production of e-learning content.

SCORM covers three main topics, described in the ADL "technical books" the *Content Aggregation Model* (ADL, 2004b), *Sequencing and Navigation* (ADL, 2004d), and the *Run-Time Environment* (ADL, 2004c). In addition, an overview of SCORM is presented in a separate document (ADL, 2004a). SCORM aims to foster creation of reusable learning content as "instructional objects" within a common technical framework for computer and Web-based learning. The SCORM technical framework consists of a set of guidelines, specifications, and standards developed by several organizations (ADL, 2004a).

The SCORM Content Aggregation Model (CAM) describes the components used in a learning experience, how to package those components for exchange between one system and another, how to describe those components so as to enable search and discovery, and how to define sequencing information for the components. In other words, the content model defines an approach to learning objects, including consistent storage, labeling, packaging, exchange and discovery of learning content. The model also describes how to create larger content packages from learning objects, how to apply meta-data to the components within the content package and how to apply sequencing and navigation details in the context of a content package.

The content model is made up of assets, sharable content objects, activities, content organizations, and content aggregation. *Assets* are the most basic learning resources, such as GIF images, web pages, HTML fragments, or Flash objects – any data that can be rendered within a Web browser or Web-based application. An asset can be composed of other assets. *Sharable Content Objects* (SCOs) are collections of one or more assets, and are the smallest elements of a learning resource that can be tracked by a Learning Management System (LMS). To facilitate reuse across multiple learning contexts, SCOs should be independent of any learning context and should be relatively small units. The next level in the hierarchy is that of *content organization*, which describes the intended use of the content within a hierarchy of activities, and sequencing information. Content organization is a mechanism for specifying the intended instructional use of the learning resources, separated from the learning resources themselves, which is a key to enabling reuse of SCO resources across learning experiences. SCORM supports such exchange of learning content between systems through a structure known as the *content aggregation*. Figure 2 (source: ADL 2004b, p. 2-5) shows an example of a SCORM content organization.

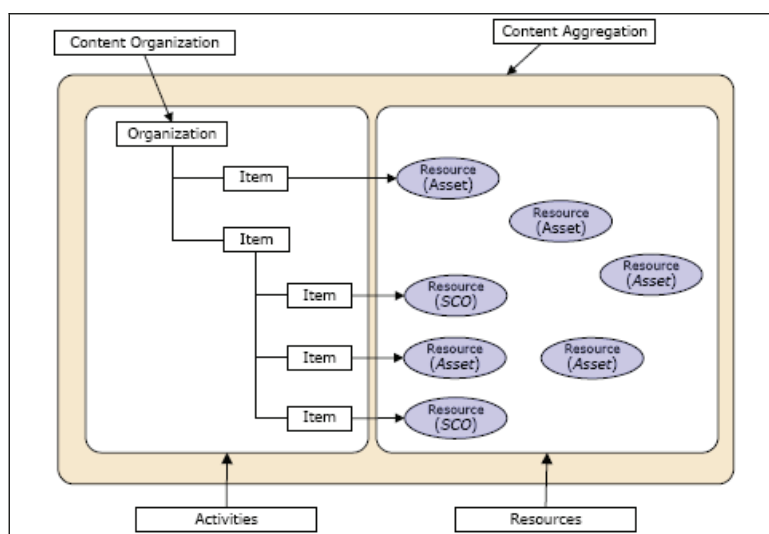


Figure 2: SCORM content organization

All elements within SCORM are accompanied by “meta data” – which is a term used to describe semantic data that is associated with the learning content, but not actually part of the content itself (e.g., the creator, the appropriate age-level, probable duration of study, media formats, etc), SCORM meta data are defined according to a standard called Learning Object Metadata (LOM) that was defined by the IEEE (Institute of Electrical and Electronics Engineers). The shared responsibility for LOM and other elements of SCORM across many organizations and developers is one of its great strengths, and SCORM is rapidly gaining acceptance as the standard for learning content around the world.

The developers of SAIL wished to benefit from the structure and reliability within SCORM, as well as to avoid any complications that would possibly derive from not being “SCORM compliant.” One important aspect of SCORM content that became central to their deliberations was the centrality of “de-contextualized learning content.” In SCORM, learning objects are represented (e.g., as SCOs) with no information concerning their intended use – expressly for the sake of encouraging repeated re-use. These learning objects can be collected in learning object repositories, which can provide valuable resources for both designers of science projects and students engaged in information gathering. The design team found no tension between this fundamental strategy of designing learning resources as learning objects and the requirements from the scaffolded knowledge integration perspective. But the aggregation of SCORM learning objects into activities and content organizations does entail some specification of instructional methodology. Indeed, the purpose of content organization in SCORM is to “provide the content developer with the means to specify cohesive units of instruction that use collections of learning resources. Such a unit of instruction is a hierarchy of learning activities, for which specific behaviors and rules may be prescribed in such a way that this activity structure and the associated behaviors can be reproduced in any SCORM-conformant LMS environment.” (ADL, 2004b, p. 3-8). The SCORM approach to sequencing and navigation raised numerous tensions within the WISE design team, as described below.

Parts of the SCORM Sequencing and Navigation book are based on the IMS Simple Sequencing (IMS SS) specification. Sequencing and navigation within SCORM describes how learning content may be sequenced for presentation to the learner through a set of learner or system-initiated navigation events. The branching and flow of that content may be described by a predefined set of activities. In addition, SCORM makes some recommendation concerning navigation controls for learners (ADL, 2004d). The specification of sequence and navigation must be explicit about its scope, with implications for which pedagogical approaches are supported: “In particular, IMS SS does not address, but does not necessarily preclude, artificial intelligence-based sequencing, schedule-based sequencing, sequencing requiring data from closed external systems and services (e.g., sequencing of embedded simulations), collaborative learning, customized learning, or synchronization between multiple parallel learning activities.” (ADL, 2004d, p. 1-7). Further, it makes clear that the specification is concerned only with the individual learner: “IMS SS recognizes only the role of the learner and does not define sequencing capabilities that utilize or are dependent on other actors, such as instructors, mentors, or peers.” (ADL, 2004d, p. 1-7).

The implications of this approach can be explored by discussing a WISE project, for example, *Genetically Modified Foods in Perspective*, a unit designed with the goal of improving students' understanding of genetically modified foods. A part of the high-level work process in this project is schematically represented in Figure 2. First, the students individually explore arguments for or against genetically modified food, or for or against or-

ganic food. Next, pairs of students prepare posters and short oral presentations. The students then present their findings for one another in peer-review, then present their arguments in a plenary discussion. After the discussion, the students individually write a paper in which they choose what type of agriculture they think should be used in their geographical region. The Virtual Learning Environment (VLE) provides support for the process as the students carry out their projects. For example, students are scaffolded in writing their paper by the use of pages which help them organize arguments and evidence for their position. As we have seen, the SCORM sequencing and navigation specification is not sensitive to events carried out by other than the individual learner. It is therefore not possible, using SCORM, to specify sequences such as the one outlined in Figure 3, (i.e. sequences that are dependent on the other group members' actions). This represents a tension between the affordances given by the SCORM (in the sequencing and navigation specification) and the pedagogical requirements of WISE inquiry projects.

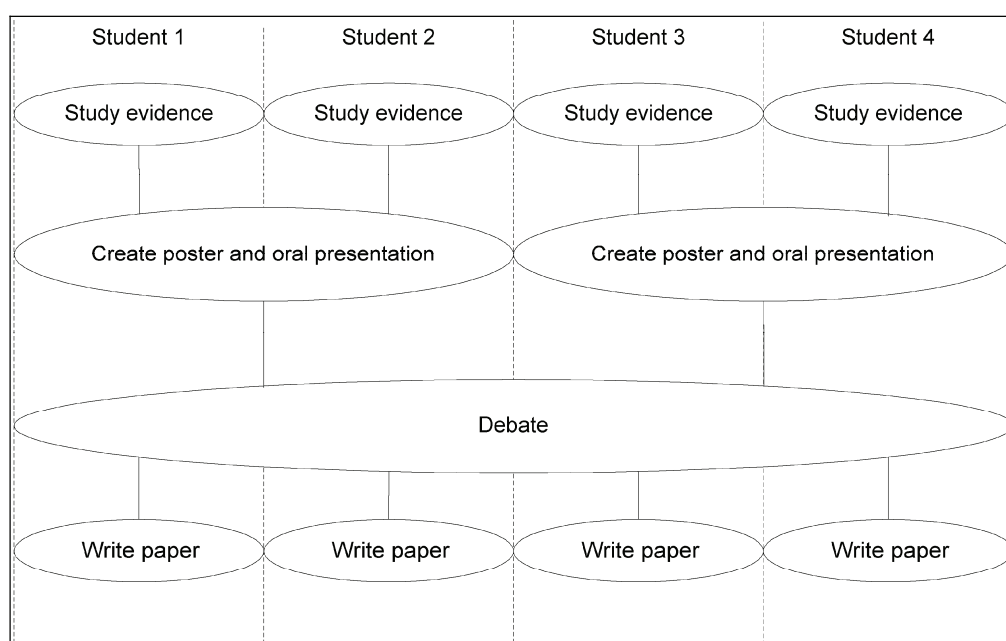


Figure 3: Part of work process in an inquiry project

Students engaged in inquiry-based learning are concerned with ill-structured problems. Therefore, learning environments should be open, meaning that they should support use of resources that are not part of the pre-prepared material. In SCORM, such resources are included in the term *Auxiliary Resources*. However, the inclusion of such resources is discouraged: “SCORM does not prohibit the use of Auxiliary Resources, however, it is recommended that content developers and LMS vendors use Auxiliary Resources with extreme care to ensure future interoperability.” (ADL, 2004d, p. 5-11). WISE employs many auxiliary resources, however, which are often of central pedagogical importance. Indeed, such open-ended learning tools (e.g., chat rooms, discussion boards, peer review galleries, or design collaboratories) are of central importance to WISE as a means of implementing the social interaction principle of knowledge integration. Therefore, this constraint imposed by SCORM represents a considerable tension with regard to the design team’s ability to express the context of use for the learning resources.

One alternative to resolve this tension could be to implement collaborative tools and other applications, such as drawing or concept mapping tools, as Shareable Content Objects. The

LOM specification, part of the SCORM content model, could probably accommodate this. For example, the metadata element *interactivityType* can have the value *active*. This is explained as “Active learning (e.g., learning by doing) is supported by content that directly induces productive action by the learner.” (ADL, 2004b, p. 4-56). Such learning objects require user data (e.g. a graphical concept map produced by a project group) to be stored in the learning management system. But SCORM limits the type of interaction data that can be specified by such objects to ten state values, and does not permit rich data such as graphics or structured scientific arguments (see ADL, 2004c, pp. 4-47 – 4-48 for details). This makes a strategy of specifying such collaborative applications as “active” learning objects challenging within SCORM.

From the perspective of the WISE design team, one requirement for inquiry-based science projects is the capability to track the actions of individual users within the context of the project group’s activity. Such tracking of both individual learners and groups can provide support for teacher intervention in the classroom as the work unfolds, as well as for assessment after the completion of the project work. SCORM provides a rich set of capabilities for tracking a students’ interaction with learning content in an LMS. These are defined in the SCORM Run-Time Environment Data Model. Examples of such tracking mechanisms are *Progress Measure*, which identifies a measure of the progress the learner has made toward completing a component; *Session Time*, which identifies the amount of time that the learner has spent in the current learner session for a component; and *Exit*, indicating how or why the learner left a component. A complete overview of the data elements are provided in the SCORM Run-Time Environment book (ADL, 2004c, pp. 4-15 – 4-16). These tracking mechanisms are all recording one individual user’s interactions with the various learning components (Sharable Content Objects). There is no concept of ‘group’ in SCORM, i.e. it is not possible to identify relations between users and therefore not possible to aggregate individual users’ interaction data into a group’s interaction data. In inquiry-based science projects, data on individual users’ actions are of limited value if they cannot be regarded in relation to the group context.

The WISE design team thus encountered several tensions between various elements of SCORM and their goals for support for inquiry-based learning in a technology framework. Said one of the design engineers: “SCORM takes a dramatically different approach from the one we hope for SAIL. They can’t be directly intermingled. The only way to put the content of one in the other is through encapsulation, where an entire SAIL-based project would be wrapped with SCORM meta-tags and treated as a large stand-alone SCORM learning object.” Said another: “In our current view of SAIL, it would probably be possible to create SCORM compliant objects that are SAIL-based, but many others would not be. We would need very explicit and restrictive guidelines for ensuring SCORM compliance.” The team next evaluated an alternative specification of learning content, called Learning Design (LD), discussed in the following section.

The VITEN project team set out to convert one of their science projects to an IMS Content Package, which could be imported into any SCORM-conforming LMS. All participating schools in this pilot project uses the LMS *IT’S: LEARNING*. Despite the vendor’s assertion of SCORM conformance, the content package could not be successfully imported, and thus had to be done manually. One challenge the team encountered was that the LMS did not recognize exercises as such. One way to work around this problem was to increase the size of the learning objects – to increase the granularity – which would greatly reduce the flexibility with regard to making modifications to the content. The IMS Question and Test Interoperability specification (IMS, 2005) could resolve this issue. The QTI specification describes a data model for the representation of question and test data, and their corre-

sponding results reports. However, the LMS did not support this specification at the time of conversion. In the VITEN environment, students can retrieve their responses to exercises and modify them throughout their engagement with the project. This functionality is not supported in the *ITS'S:LEARNING* LMS, and it is neither a part of the IMS QTI specification. The pilot project has also encountered problems similar to those of the WISE team. For example, the collaborative writing tool in the VITEN environment could not be specified in a content package. The pilot project has used the AICC specification for communication between the learning objects and the LMS, which is also used in the SCORM Run-Time Environment specification. The experience from the pilot project is congruent with the WISE team's deliberations: tracking of student activities in the context of group work was found to be problematic.

Data from the VITEN pilot project is currently being analyzed. One preliminary finding is that the teachers utilized the opportunity to modify the sequence of learning content and activities to a varying degree. Some teachers, maybe the most inexperienced, preferred to take advantage of the considerable knowledge and effort put into the selection and sequencing of the material by the VITEN designers. Others made modifications, and included some of their own material. This is in line with one goal of both WISE and VITEN – to provide high-quality science curriculum that could be used un-modified, but that is versatile enough to accommodate teachers who prefer to customize the material according to their preferences and requirements. Such a view is consistent with the approach taken by IMS Learning Design, discussed in the following.

### ***IMS Learning Design***

The IMS Learning Design Specification (IMS, 2003a; IMS, 2003b; IMS, 2003c) was created to promote exchange and interoperability of e-learning materials, with a focus on facilitating reuse of teaching strategies and educational goals. The specification is based on the Educational Modeling Language from the Open University of the Netherlands (Oliver & Tattersall, 2005). Part of the background for this work was a view that “to date, specifications for learning objects have primarily been designed to ensure interoperability at a rather low infrastructural level [...], focusing on technology issues and reuse of learning objects.” (Hummel *et al.*, 2004, p. 111). The fundamental idea is to associate educational content with information describing its instructional strategy, which can be used for adapting the content to a pedagogical approach that is different from the one for which it was designed. “By labeling the strategy and the components of the strategy in a common, machine-readable manner, the context of a learning opportunity can be managed separately from the content itself” (IMS, 2003b, p. 4). This specification can thus be regarded as a way to implement pedagogical patterns (e.g. Eckstein, Manns, Sharp & Sipos, 2003), but with much more specific descriptions of instructional strategy and the capability to indicate concrete learning resources to be used with the strategy.

The objective of IMS LD is to provide a containment framework of elements that can describe any design of a teaching-learning process in a formal way. In order to achieve this, IMS has set out a set of high-level requirements for the specification (IMS, 2003a, p. 8). These are concerned with completeness, pedagogical flexibility, personalization, formalization, reproducibility, interoperability, compatibility, and reusability. The issue of completeness means that the “specification must be able to fully describe the teaching-learning process in a unit of learning, including references to the digital and non-digital learning objects and services needed during the process” (IMS, 2003a, p. 8). This implies support for both single and multiple user models of learning, and support for mixed-mode as well as pure online learning.

The IMS LD provides a "meta-language" which can be used to describe a wide range of pedagogical approaches. These are captured by describing a *method*, prescribing *activities* for participant *roles*. The method is essentially a *play*, envisioned as a theatrical play, where the teaching-learning process is described by specifying which roles perform which activities in what order. In addition to the play, a method can include *conditions* for directing learning activities, using *properties* from the learner portfolios. Conditions and properties enable personalization and more elaborate sequencing. Activities describe the actions the role has to undertake within a specified environment composed of learning objects and services (e.g. discussion forum or drawing tool). The learning objects and services in the environment are referenced to in a Learning Design, but they are not part of the LD. The learning activities in a unit of learning are modeled in the LD. This is how the educational content is separated from the instructional strategy in the LD specification. Activities can be of the two types: learning and support activities. A learning activity is directed at achieving a learning objective per individual user, and includes a single activity-description (which could be text, audio, or video). A support activity is meant to facilitate a role performing learning activities. There are two basic role types, Learner and Staff. Roles can be given names depending on the context, and they can be sub-typed. More than one user can be assigned to a role during run-time.

While the WISE design team did find that IMS LD could accommodate technology-enhanced inquiry science projects as they are envisioned in the SAIL framework, they were less clear about what could be gained from implementing an LD specification. The value added by IMS LD is primarily related to the ability to be explicit about the instructional approach and learning activities. Moreover, it is possible to specify projects that are sufficiently flexible to be adapted to specific classroom contexts (e.g., customizations by teachers). The LD specification allows for students' un-anticipated use of learning resources, and for adjustments to the progress of the projects by both students and teachers. As a consequence of the separation between the specification of the instructional strategy and the learning resources to be used with that strategy, IMS LD places few restrictions on what kind of resources and tools that can be specified as a part of the learning design. Books, persons, or software tools for individual or group production (e.g., a word processor or concept-mapping application), as well as other physical artifacts can all be included.

One of the major strengths of SCORM is that it provides a set of specifications that cover many aspects of design and deployment of digital learning material, with the aim to "provide a comprehensive suite of e-learning capabilities that enable interoperability, accessibility and reusability of Web-based learning content." (ADL, 2004a, p. 1-5). The scope of IMS LD is different; the goal is to "enable many kinds of educational designs to be created, using a consistent notation, which can be implemented uniformly in multiple courses or learning programs." (IMS, 2003b, p. 5). For example, IMS LD does not set out to specify the mechanics of delivering a unit of learning, and specification of the mechanics of the process of interpreting content from one model to another is regarded as out of scope. (Ibid., p. 6). This means that specification of requirements for run-time environments to a large degree is absent, even though some suggestions are given in the behavioral model (IMS, 2003a, pp. 68 – 79) and in the Best Practice and Implementation Guide (IMS, 2003b). While the educational method and learning activities in a unit of learning is modeled in IMS LD, the environment (learning objects and services) is modeled outside the specification. SAIL is concerned with specifications for the development of reusable and interoperable learning content, services, as well as instructional strategies (projects). Thus, IMS LD does not cover all aspects addressed by SAIL.

As a relatively new specification, IMS LD is not widely supported in authoring tools, Virtual Learning Environments (VLEs), and Learning Content Management Systems (LCMSs). Two of the key architects of the specification states that “the principles and standards are defined, but most of the tooling still has to be developed.” (Koper & Tattersall, 2005, p. vi). One early initiative based on the conceptual model of LD is LAMS (Dalziel, 2003). Due to a range of practical problems with the LD specification during implementation, LAMS is currently not conforming to IMS LD. However, the Open University of the Netherlands has developed an IMS LD engine, CopperCore. This engine, which implements “the business logic” of Learning Design, is used in the Reload Learning Design Player developed by the RELOAD project. This project has also developed the Reload Learning Design Editor, an authoring tool which is a reference implementation of LD. One concern is that LD is too open-ended, making it challenging to develop systems that validly implement the LD standard. Specifying SAIL-based projects according to LD does not, however, imply that SAIL-based technologies such as VLEs, authoring tools, or LCMSs should be fully compliant with LD. Obviously a VLE, for example, needs to be able to make the resources available to the participants as specified, but the SAIL group does not set out to make a reference implementation of the LD.

The WISE design team found several aspects of LD that were well aligned with their content goals for SAIL-based science projects. The substantial work done on the specifications would enable project designers to specify both the instructional strategy for the project and learning resources that could be used in it. The LD specification would facilitate the sharing and reuse of emergent best-practice with respect to how to implement inquiry-based science projects in classrooms. Moreover, LD could help SAIL ensure that learning resources were accessible to teachers and students working outside of the SAIL framework, and might ease inclusion of projects created outside the context of SAIL within SAIL-based curriculum.

Building on their substantial design discussions, SAIL has now been specified and implemented, and is offered as an open source framework for learning objects and core services at the following web site: <http://sail.sorceforge.net>. The designers of SAIL are currently developing a new learning content management system that will also be open source, and will hopefully bridge the content of WISE and VITEN. In this development effort, designers are looking carefully at the IMS LD as a resource for enabling the description of pedagogical content in a SAIL-base authoring system. This work is ongoing, and is described in further writings available at the SAIL Web-site listed above. One aim of the work is to establish an international community of developers who co-design an open source framework for pedagogically rich learning content, including interactive inquiry curriculum.

## Conclusions

The sections above presented an analysis of learning technology specifications that is of great importance within the learning technology research community. The WISE research project has experienced substantial pressure to comply with SCORM in its representations of learning content, and lacked any solid explanation for why they should or should not redesign their learning content accordingly. Based on their requirements for a pedagogical approach of technology-enhanced inquiry, we analyzed affordances and constraints of two specifications (SCORM and LD) to provide such an explanation. The SCORM framework is well developed and widely applied in the e-learning industry, and predominantly accommodates pedagogical designs where single users work on structured problem domains and interact with digital learning content without support from teachers or peers. We observe that, when de-contextualized learning resources are aggregated into larger units, tensions

appear between the SCORM specification and a designer's intentions for creating inquiry science projects. Important issues such as the ability to express collaborative activities, track students' activities in a group context, support for and sensitivity towards teacher intervention, and accommodation of students' un-anticipated use of learning resources are problematic. We have found SCORM's specification of learning objects, using the IEEE LOM standard, to be consistent with SAIL's goals concerning sustainable learning resources, and the team will continue the work on incorporating this standard in the SAIL framework.

The IMS Learning Design specification responds to the lack of pedagogical flexibility in SCORM. The major contribution of IMS LD is its capability to express the designer's instructional strategy together with the resources prepared for the learning situation. Our analysis indicates that inquiry-based science projects can be fully described within this specification. We regard IMS LD as promising with respect to the high-level goals of SAIL, where experience accumulated through project runs can be shared and form a basis for refining the projects. IMS LD is not yet widely deployed, but has potential to become a central means for reusability and interoperability of learning resources across learning technology platforms. The SAIL group will therefore continue to explore the possibility for SAIL-based learning resources to comply with IMS LD.

Our analytic framework, inspired by activity theory, allows a means of investigating the design process within a learning technology development project, where many decisions are made in response to complex goals and constraints. The specific pedagogical emphasis of inquiry science is shared by many within the CSCL community, and the challenge of deciding about SCORM is one that many projects will encounter. Moreover, our findings are also applicable to other pedagogical approaches and problem domains, applying generally to student-centered learning designs, collaborative learning designs, and project-based approaches, particularly where the problem is ill-structured and resources are open ended. Additionally, the technology challenges articulated are common to projects where the computer is only one of several resources available to the learners, or where multiple technology media are employed. We find that such analytic analyses can illuminate the underlying formalisms within learning technology projects, and help delineate fundamental assumptions or requirements of such platforms. The pressure to conform to learning technology specifications like SCORM will be an ongoing source of pressure for developers, and this process of analyzing the affordances and constraints of the activity system can help the process become a productive one.

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## Biography

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# Appendix B

## Paper II

Fjuk, A., Berge, O., Bennedsen, J. and Caspersen, M (2004)

*Learning Object-Oriented through ICT-mediated Apprenticeship*

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# Learning Object-Orientation through ICT-mediated Apprenticeship

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## Abstract

*In this paper, we show how sociocultural theories inform the design of a course in object-oriented programming. An essential learning objective within this philosophy is the programming processes as such. To move toward this learning goal, the course design incorporates a combination of the so-called person-centered and decentered approaches to apprenticeship learning. Our preliminary analysis indicates that the person-centered approach to apprentice learning has been very successful, while the decentered approach is found to be more problematic when it comes to practice. The reason behind this is discussed.*

## 1: Introduction

It is widely accepted that activities directed towards object-oriented programming and modeling require different ways of thinking and different approaches than procedural development activities. In agreement with this line of thought, there is a long tradition in discussing the challenges around teaching and instructional design connected to introductory courses in programming (SIGCSE; OOPSLA, etc). We argue, however, that there has been a lack of explicit foundation in learning theories underlying past research and course design. The field tends to have a narrow focus on language constructs in a particular programming language and tools for understanding this, rather than consciously considering these issues as incorporated aspects in a greater learning activity. As a consequence, the important analytical issue of how programming as a knowledge domain is created by the individual as well as what aspects are considered as critical for the individual's understanding, are both

missing. Many computer science educators have no formal training in education [8, 3] or do not have capacity to do research on this area besides their own research area in computer science.

Our core argument is theoretically grounded in sociocultural theories on learning. This paper is concerned with how these theories can inform design of a model-based introductory programming course (Introduction to Object-Oriented Programming, IOOP), at University of Aarhus, Denmark. In addition to the particular model-based philosophy, the characteristics of the target group have essential impact on how the learning theory is incorporated into the course design. The target group of the course is adult part-time students, committed to different work organizations, families, geographical places, etc. Given this situation, the learning activities need to be provided in a flexible manner. A conscious combination of new information- and communication technologies (ICTs) facilitate for organizing learning activities across individual constraints such as technical infrastructure, profession and experiences as well as preferences with regard to learning style.

## 2: Method

The research is based on a case study of IOOP carried out during the fall semester of 2003. The unit of analysis for the case study is *the learning activity*. This means that the focus of our analysis is on the constellation of learning resources and what effect each of them have on the learning activity. We believe that the relationships between these resources are rather interwoven, implying that it is complicated, sometimes even impossible, to consider which ones that are *most critical* with respect to the learners' understanding of object-oriented programming.

The data gathering has been carried out by observation of the online activities and weekend seminars, and by in-depth interviews with 9 students, the teacher, and the teaching assistant. Finally, this study is supplemented by a survey carried out among the students as a part of the course evaluation.

### 3: Theoretical foundations

To illustrate the importance of using learning theories in the course design, we will focus on a core set of concepts that we, first, considered as important for understanding the particular case of IOOP and, then, for understanding the role of ICTs herein (e.g., Vygotsky [15, 16], Leont'ev [12] and Davydov, Zinchenco & Talyzina [4]).

The core argument for using sociocultural theories is the focus on the social and contextual dimension of knowledge construction and the rich approach of understanding the inseparable role of artifacts. The learning theoretical heritage from Vygotsky [15,16] is that knowledge construction is social by its very nature, and that intellectual development takes place on two levels: First it appears on a social level, through interpersonal interaction. Then it appears on an individual level through intrapersonal interactions. These interactions take place through a range of actions that are directed towards conscious objectives.

The actions have operational aspects, i.e., the way the action is actually carried out. The notion of artifact mediation becomes fundamental in this respect. Artifacts are incorporated parts of the actions, they carry with them a particular culture and history, and – as such – influence how human actions are operationalized. Because of this nature of artifacts, they should not be considered as given, but be viewed inseparable from every human activity. Many computer-based artifacts occupy interrelated roles as both means for thought and reflection and as tools for operationalizing the same action. A text-based communication system (e.g., chat, e-mail, etc) is one typical example and the object-oriented language Java is another example. Java can be regarded as an artifact for operationalizing an object-oriented approach to program code. It may serve as a means for thinking into this perspective on programming, but at the same time providing a communication language for communities of programmers. Moreover, object-oriented programming languages contain some fundamental different principles than e.g., procedural programming languages, implying that a comparable task will be performed completely different by these two types of artifacts.

The sociocultural groundwork has received vastly differing interpretations, under which knowledge construction (and intrapersonal processes) play different roles. One widely known interpretation is how the stu-

dent internalizes the scaffolding and guidance of more capable peers. The pedagogical approaches seek to provide instructional support for performance of tasks and are often conceptually tied to the pedagogical intentions of teachers and other caregivers. Without explicitly referring to this theoretical foundation, we argue that the CS1 area is dominated by this instructional view, however, without any clear interpretation of how learning takes place. For example, Bergin [3] has developed pedagogical patterns that are generally aimed at providing – in a uniform way – solutions to common problems in teaching object-oriented programming. These patterns serve as artifacts for mediating the teaching activities, but do not in any strong sense include basic theoretical principles of learning [2]. The work of Kölling and colleagues [10] on the BlueJ environment is another example. The background for developing BlueJ is the challenges around teaching object-oriented programming and, the pedagogy behind BlueJ is reflected upon such a view by describing instructional guidelines [10].

Recent interpretations of sociocultural perspectives take collective and societal perspectives rather thoroughly into considerations. The works of Engeström [7] and Lave & Wenger [11] have significant positions in this respect. These interpretations extend the study of learning beyond the context of pedagogical structuring and schooling, and focus on the contradictory nature of social practice. According to Engeström, learning is the mastery of expansion from everyday actions of individual to new activity collectively generated as a solution to so-called double-bind situations. The work of Engeström has influenced a variety of studies within the computer science field.

Lave & Wenger [11] share the focus on social processes of learning with Engeström, but place more emphasis on connecting issues to sociocultural transformation with the changing relations between newcomers and old-timers in the context of a changing shared practice [11]. With an absence of what we traditionally know as formal teaching in apprenticeship, crucial issues are what promote the learning process, what actions must be focused and how to structure the social interactions. In the context of IOOP, one important learning objective is the *processes of programming* [1]. This means that it is regarded as important that the students gain insights into how programmers develop their solutions from the initial problems, e.g. how one frequently compile code, use documentation and test partial solutions. One way of attaining this goal is to expose the students to how an expert programmer works. Another is to consider the student as an active participant in a community of co-students. Concerning the former, it is close to what Nielsen & Kvale [13] term a *person-centered approach*. The master reflects and thinks aloud of the particular action, making them visible and as a source of



identification (Ibid.). As such, the apprentice learns from observing the master (teacher) performing the actions embedded in the profession (e.g. coding, testing, etc). From this particular position, the role of language (oral and written) becomes important. This is in accordance with Vygotsky's distinction between scientific (specialized language such as e.g., programming languages) and everyday concepts, and on his argument that a mature concept is created when the scientific and everyday versions have merged. Thus, it is the master's role to contribute to the merge between these two types of language by articulating around his actions.

Furthermore, the master's comments to the student's practice have an important position in the student's reflection in action (cf. [14]). Concerning the latter, it is described as a *decentered approach* by Nielsen & Kvale [13]. Knowledge construction is considered as legitimate peripheral participation, i.e., the attention is on the student's inevitably participation in communities of practitioners where the old-timers legitimate the skills and knowledge of the individual newcomer. The student is the apprentice and the teacher (or more capable peer) is the expert in the social interactions. Mastery does not reside on the master, but on the organization of the community (of which the master is a part) and on the structuring of a community's learning resources (ibid.).

The next section is concerned with how a combination of the two approaches has inspired the course design, as well as what ICTs and learning resources were selected to operationalize the actions in the interactional processes.

## 4: The design

One important aspect in introductory programming courses is the role of the programming language. Knudsen and Madsen [9] identify three perspectives: Instructing the computer, managing the program description, and conceptual modeling. A central issue pertaining to the design is the decision to maintain a balanced view on these three aspects in the course design. The primary outcome of this choice of balancing is that the student should understand the programming processes through a systematic approach to programming and, to construct knowledge on general programming concepts instead of just language constructs in a particular programming language. The rationale for this choice is described in more detail in [1].

### 4.1: The person-centered approach

Given the learning objective stated in the previous section and operationalized through a person-centered approach, the duality of the relationship between the student and the teacher becomes important. Obviously, the student must be able to observe the master in his

practice, but the master also needs to gain insights into the student's understanding. When the teacher's role is to legitimate the skills and knowledge of the student, the teacher needs a fairly deep understanding of the level of skills - otherwise it is very difficult to legitimate anything. This section shows how this relationship is mediated by a constellation of the following artifacts: Weekly assignments, on-line meetings and pre-produced video material.

The *weekly assignments* are designed as programming exercises, and they are based on the readings and exercises scheduled for the corresponding weeks. Each assignment is designed as a means for understanding the practice of programmers as well as for engaging in the process of creating object-oriented computer programs. Together with Java, the Blue J environment is used by the individual to operationalize these sets of actions. Moreover, the assignment is a fundamental means for interaction between student and teacher, and thus for legitimating the student's actions towards the problem. As such, the apprenticeship approach implies a change *from* viewing the assignments as control / evaluation mechanisms *to* a communicative artifact between the master and the apprentice. The assignments are therefore not part of the final grade but used with the communicative purpose and as a way of structuring the student's time.

In order to enrich the pedagogical philosophy of the assignment, a corresponding *weekly online meeting* is conducted. The topics treated in these meetings are based on the individual student's experiences in solving the assignment, combined with her/his request posted in an asynchronous discussion forum beforehand. This approach denotes a particular mode of engagement and participant control, at the same time as the teacher legitimates and shows how programming / modeling processes associated with the weekly problem areas can be approached. The online meetings are mediated by real-time video streaming of the teacher's PC screen, where his use of the various programming and modeling tools are shown. There is a corresponding audio stream, where the students can hear how the teacher reason and think aloud about the problem. In some theories of apprenticeship, the use of language is considered crucial in the master-apprentice relationship. This is pertinent for the apprentice's learning while the master is performing the actions of the craft of programming. But it is also important in order for the teacher to get a feeling of the skills and knowledge of the students, and in particular in situations where the teacher and the students are geographically separated. In order to support interactions amongst students and between student and teacher during the online meetings, a text-based chat conference in conjunction with the real-time audio- and video streams are organized.

Another artifact organized to facilitate the students' knowledge construction while working on the weekly assignments, is a collection of short *pre-produced video demonstrations* of how to approach specific issues. These are made in a similar manner to the online meetings; there is a video stream showing how the teacher approaches the problem together with an audio stream where the teacher thinks aloud. The difference from the online-meetings is that these demonstrations are available at any time, and that there is no opportunity for interaction. However, this specific technique is coming out of the basic principle of the person-centered approach where the teacher should explicitly legitimate the students' problem solving.

Such a demonstration typically involves modeling and programming in the Blue J environment, including frequent compilations that sometimes reveal (intentional) syntax or logical errors, tests of parts of the solution, and consultation of Java SDK documentation. In this way there is a focus on the programming process as well as the conceptual understanding of object orientation

#### 4.2: The decentered approach

Founded on the decentered approach, the idea behind the design is to create opportunities for the students to participate in an actual practice of programming experts so as they gradually learn through legitimate peripheral participation. This can be further operationalized by utilizing the different backgrounds of the adult students so as they become each other's experts and legitimates in the shared learning community. Theoretically, individual knowledge is mediated by the apprentices' shared interests in learning object-oriented programming and by the ICTs and other resources (s)he has available.

This important social aspect of learning is taken into the pedagogical design, and operationalized through both technological and organizational elements. On the *technological side*, the course design facilitates for collaboration by offering the students tools for text-based communication. All the students installed the chat client *Yahoo! Messenger*, and registered all the course participants as "friends" – enabling them to see who of their peer students that is available for interaction at any given time. Thus, in addition to acting as a tool for planned collaborative events, *Yahoo! Messenger* also gives the students opportunities for more spontaneous interaction. Additionally, there is a web-based discussion forum available for the students. This tool is aimed at mediating the student's dialogues with peer-students where time is not a critical factor.

On the *organizational side*, there are two important mechanisms for supporting the social interactions amongst students. During the course, the students meet physically for three two-day seminars. One central aspect of these weekend seminars is to stimulate collaborative

activities while the student works distributed. Experience from net-based learning points to the importance of such face-to-face meetings for online collaboration [5]. The other mechanism is that the students are divided into groups. These groups are put together based on where the students live, in order to make physical meetings outside the weekend seminars easier. The student groups are given tasks during the weekend seminars, and they are encouraged to work together during the full length of the course.

#### 5: Concluding remarks

In this paper, we have shown how sociocultural theories have informed the design of a course resting on a model-based philosophy of object-orientation. An essential learning objective within this philosophy is the programming processes *as such*. This means that the individual student should construct knowledge on how programmers develop their solutions from the initial problems to the final code. To move toward this learning goal, the IOOP course design has incorporated a combination of the so-called person-centered and decentered approaches to apprenticeship learning. In combination with more general sociocultural theories on human development, they constitute a rich framework for understanding the role of artifacts with respect to the student's appreciation of programming processes.

Our preliminary analysis of IOOP indicates that the person-centered approach to apprentice learning has been very successful, while the decentered approach is found to be more problematic when it comes to practice. There are at least three aspects that make the decentered approach to apprenticeship problematic for our target group. First, the students are novices in object-oriented programming and may as such be too immature to play a role as experts for co-students. Second, ICT-mediated collaboration requires a well-orchestrated interdependence amongst the students (requires sharing of meaning, certain division of labor, etc.) [6], and a certain level of regulation and tutor guidance are often desired to succeed [5]. Third, and certainly in line with the second argument: due to the life situation of many of the students (committed to family and work besides their study), individual study – which allows for greater flexibility – was preferred to collaboration with peer students.

Our preliminary analysis indicates that the aspects of the course modeled on the person-centered approach to apprenticeship, were more successful. There are, however, issues to be addressed in this design of the online meetings too. In the beginning of the course, the interactions during the online meetings were mediated by text chat, enabling the students to ask questions when they had problems. The outcome of this technical design was silence! This led to a change in the use of the chat

application, i.e., much more interaction was initiated by the teacher where he raised questions etc. to the students. Further elaboration on this part of the design is needed.

## 6: Acknowledgments

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<sup>1</sup> <http://www.intermedia.uio.no/cool/>

<sup>2</sup> <http://www.it-vest.dk/aktiviteter/index.shtml>



# Appendix C

## Paper III

Bennedsen, J., Berge, O. and Fjuk, A. (2005)

*Examining social interaction patterns for online apprenticeship learning  
– Object-oriented programming as the knowledge domain*

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**Examining social interaction patterns for online  
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## **Abstracts**

### English Abstract

The article shows and discusses social interaction patterns that developed in an online learning environment where the pedagogical design was inspired by ideas found in apprenticeship learning. The embedded study comprised a case study of an introductory online course on object-orientation and a design experiment carried out in the same course in the following semester. The case study indicates that support for the teacher's awareness information on the learners' level of knowledge and progression is critical for successfully developing social interaction patterns of teacher guidance. The design experiment identified that learners' pre-prepared solution of the problem was vital means for developing productive social interaction patterns concerning collective reflections and joint problem solving.

### Danish Abstract

Denne artikel viser og diskuterer sociale interaktionsmønstre som udviklede sig i et virtuelt læringsmiljø hvor det pædagogiske design var inspireret af ideer fra mesterlære. Studiet bestod i et case-studie af et online kursus i introducerende objekt orientering og et design eksperiment som blev udført i same kursus semesteret efter. Case studiet indikerer at underviserens viden om de studerendes vidensniveau og progression er kritiske for en succesfuld udvikling af sociale interaktionsmønstre i forhold til vejledning fra underviseren. Design eksperimentet identificerede de studerendes forberedte løsninger af et problem som en vital hjælp til at udvikle produktive sociale interaktionsmønstre for kollektiv refleksion og fælles problemløsning.

### Norwegian Abstract

Denne artikkelen presenter og diskuterer sosiale interaksjonsmønstre som utviklet seg i en nettbasert læringsomgivelse hvor det pedagogiske designet var inspirert av mesterlære. Undersøkelsen bestod av en case-studie av et nettbasert introduksjonskurs til objekt-orientert programmering, og et designeksperiment utført i det samme kurset påfølgende semester. Case-studiet indikerer at støtte for lærerens awareness-informasjon knyttet til studentenes kunnskapsnivå og progresjon er kritisk for å utvikle sosiale interaksjonsmønstre for lærerveiledning på en god måte. Designeksperimentet identifiserte studentenes individuelle løsningsforslag som en sentral ressurs for å utvikle produktive mønstre av sosial interaksjon relatert til kollektiv refleksjon og samarbeidsrettet problemløsning.

### Keywords

Distance learning, apprenticeship, programming, CSCL.

## **Introduction**

The first steps towards what we today label online learning were taken in the late 80s. Distance education institutions and universities started to realize the potential of using ICTs (Information and Communication Technology) to facilitate (adult) learners' collaboration across place and time constraints (e.g. Mason & Kaye, 1989; Harasim, 1990; Paulsen 1990; Feenberg, 1991; Kaye,



1992; Hiltz & Turoff, 1994). The ICTs implied institutional and educational changes (as discussed in Cole & Engeström, 1993). However, the changes did not seem to transcend the existing practices in terms of the new social interactions and collaboration patterns that developed with the new artefacts (See e.g. Fjuk, 1998; Fjuk & Øgrim, 1997; Rovay, 2004; Cuban, 2001; Murchu & Sorensen, 2004).

Recently, a variety of services and applications are increasingly becoming easily available from everyone's PC. In contrast to the early days of online learning, this technological situation allows to a larger extent course designers to focus on how the learning activities and corresponding learning objectives can be approached through the new ICT-mediated and online environments. An increasing number of studies have explored different issues that are valuable in this respect. For example, Paulsen (1995), Hara and Kling (2000), Salmon (2000), and Stahl (2001) explore the teachers' new roles. Others discuss how ICTs influence patterns of collaboration and social interactions (e.g. Krange, Larsen, Fjuk & Ludvigsen, 2002; Wasson & Ludvigsen, 2003), the importance for meta-communicative actions and commitment in problem-oriented learning at a distance (Fjuk & Dirckinck-Holmfeld, 1997), and various forms of awareness information related to online collaborative learning (Gutwin, Stark & Greenberg, 1995; Cao & Greer, 2003; Krange & Fjuk, 2004). Finally, some studies provide insight into the employment of pedagogical approaches that are theoretically grounded in co-located situations, such as problem oriented project pedagogy (Fjuk & Dirckinck-Holmfeld, 1997), case-based learning (Hermann, Rumel & Spada, 2001), progressive inquiry learning (Hakkarainen, Lipponen & Järvelä, 2002; Ludvigsen & Mørch, 2003) and problem-based learning (Zumbach & Reimann, 2003).

The study reported in this article is a contribution to this emerging body of research. The aim of the study was to examine the social interaction patterns that develop in online learning environments, where the pedagogical design is motivated by ideas from apprenticeship learning. Apprenticeship learning is theoretically anchored in situations different from online and educational situations. Few studies have explored what social interaction patterns that develop amongst learners and between learner and teacher in online apprenticeship

motivated learning environments. The identified interaction patterns provide insights into how social interaction amongst learners and between learner and teacher improve collective construction of knowledge, and how to integrate these patterns in future course designs.

The knowledge domain of the study was *Introduction to Object-Oriented Programming* (IOOP), delivered by the University of Aarhus in Denmark. The distributed organization and extensive application of ICTs represented in this online course design was regarded as potentially illuminating towards exploring a subset of social interaction patterns, given the particular knowledge domain. The patterns were identified by using *interaction analysis* in rich combination with online observations and in-depth interviews with learners and the teacher.

The following section presents IOOP in terms of learning objective, pedagogical approach, and the design of the networked learning environment. Next, our research approach is described, followed by a section presenting and analysing data from the study. This article concludes with a section discussing the main findings, and a conclusion proposing some implications of our research for design of online learning environments.

## **Course design considerations**

To examine the social interaction patterns and how the social interactions influence collective knowledge construction, it is vital to relate the analysis to the subject matter (object-oriented programming) and the original online course design. Thus, this section first gives a brief overview of the course under study and its principal learning objective. Next, some interpretations of apprenticeship learning are introduced and discussed in relation to the particular course. Finally, this section describes the application of these facets of apprenticeship in the online course design.

### **The learning objective**

The course *Introduction to Object-Oriented Programming* (IOOP) has been taught as an on-campus course at Aarhus University in Denmark during the last decade. The principal learning objective is the *processes of programming*,

rather than the final products (e.g. a program written in Java). Programming is arguably a creative and analytical activity where the programmer starts with a vague idea of a solution, then – in some non-formal and non-linear way – articulates and models the thoughts into an executable program. A pedagogical approach that enhances such a creative activity in itself, in rich combination with showing the learners how an expert programmer works in these processes, has gradually been considered vital for the course design. However, modern pedagogical perspectives that emphasise an understanding of language, culture and the cognitive development that occurs through interactions between learners as well as between learners and teachers (Scott, Cole & Engel, 1992) have not been consciously included in the on-campus course. The online learning course design aimed at incorporating collaborative knowledge building processes. In this perspective, learners actively generate, access and organise information, constructing and refining their own knowledge through feedback from peers and the teacher.

### **The pedagogical approach**

The most significant source of inspiration behind the pedagogical approach was conceptual frameworks offered by apprenticeship learning. Traditionally, theories on apprenticeship learning concern the learning of a craft in the community of practice where the work is carried out (Lave & Wenger, 1991; Lave, 1996; Nielsen & Kvale, 1997). Through social interactions between the experienced master and the apprentices, the apprentice progressively creates a deeper understanding of the profession (Aboulaflia & Nielsen, 1997). Nielsen & Kvale (1997) describes two facets of apprenticeship: the person-centred facet and the de-centred facet. In the *person-centred facet*, the teacher reflects and thinks aloud about the particular action, making it visible and a source of identification (ibid.). As such, the learner creates meaning in observing the teacher performing the actions embedded in the profession (such as the creative and analytical activity of programming). Furthermore, the teacher's comments on the learner's practice have important bearing on the learner's 'reflection in action' (Schön, 1983). In the *de-centred facet* of apprenticeship, knowledge construction is considered as a kind of legitimate peripheral participation (as described by Lave & Wenger, 1991). The attention is on the learner's participation in a community of practitioners where the

teacher or a more experienced peer legitimizes the skills and knowledge of the individual learner. Mastery does not reside exclusively in the teacher alone, but in the community (of which the teacher is a part) and on the structuring of the community's learning resources (ibid). In most situations, a dynamic balance between the person-centred and the de-centred facet is practiced.

The conceptual framework of cognitive apprenticeship (Collins, Brown & Newmann, 1989) offers insight into how aspects of apprenticeship learning is applied into formal education and schooling. A central concept herein is modeling that is "supposed to give models of expert performance. This does not refer only to an expert's internal cognitive processes, like heuristics and control processes, but also to model the expert's performance, tacit knowledge as well as motivational and emotional impulses in problem solving" (Järvelä, 1995, p. 241). The teachers give the right level of support while the learners are solving problems. An important issue of cognitive apprenticeship is that the learners' reflection on the differences between her / his knowledge and the reflections made by the master and fellow learners.

The frameworks offered by cognitive apprenticeship, person-centred apprenticeship and de-centred apprenticeship gave inspiration for the course design. A common assumption in these frameworks, however, is the co-location of the actors (teacher and learners), which was not the case in IOOP. The interaction frameworks of *teleapprenticeships* offer some insight into this problem area. Teleapprenticeships are teaching frameworks for apprenticeship-like environments without requiring the actors to be in the same places at same times (Levin & Waugh, 1998), and to support learning in the context of a remote practice. The frameworks allow novices to learn through participation in a remote community of practice, initially observing the online interactions, then handling small tasks to accomplish with guidance and finally taking roles that are more substantial during the extended interaction. This approach differs from the online IOOP course in a significant issue: The learners are taking part in an online community of learners and teacher, and not in an online community of professionals. Their daily work situation maintained their commitments to a community of professionals.

The focus in IOOP is on showing the learners how a professional thinks and acts in a complex process of analysing and solving problems, i.e. modelling in the cognitive apprenticeship terminology. A vital aspect of the online course design was then to organize ICT-based applications that were easily accessible from the learners' PCs (preferable from their homes) and that provided quality given the pedagogical constraints.

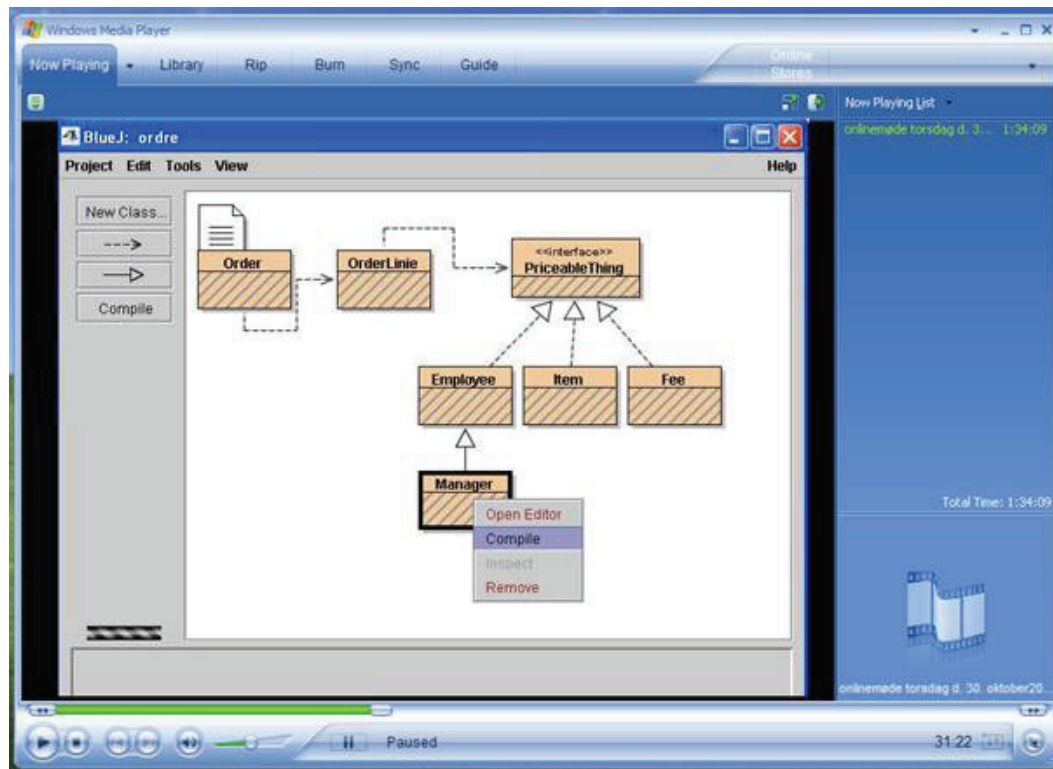
### **The online learning environment**

To organise a dynamic mix of the pedagogical constraints found in apprenticeship learning, it first implies instruments for enhancing information sharing and joint creation of meaning amongst the learners. Second, it implies instruments for supporting the teacher's reflection in action in terms of both natural and scientific language, as well as for showing the creative process of programming. Finally, it implies instruments for supporting awareness information on the learner's knowing and progression<sup>1</sup>. In the following, we will focus on the instruments most central in organizing the online learning environment: the *online meetings* and the *assignments*. Fjuk, Berge, Bennedsen, and Caspersen (2004) give a more thorough account of the course design.

The online meetings were mediated by real-time video streaming of the teacher's PC screen, showing his usage of the various (programming) tools. Figure 1 shows an example of how the video stream appears for the learners. In the corresponding audio stream, the learners can hear how the teacher reasons and thinks aloud about the problem; an externalization of the teacher's internal processes "Seeing how experts deal with problems that are difficult to them is critical to students' developing a belief in their own capabilities. Even experts stumble, flounder (...) Witnessing these struggles helps students realize that thrashing is neither unique to them nor a sign of incompetence" (Collins & al., 1989, p. 473). In order to support interactions amongst learners and between learner and teacher during the online meetings, a text-based *Instant Messaging (IM) conference* was set up in conjunction with the real-time audio- and video streams.

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<sup>1</sup> See Dourish & Bellotti (1992) for the introduction of the term. Awareness is here understood as an understanding of the activities of others, which provides a context for one's own activity. See also Krange & Fjuk (2004) for discussion on its pedagogical application area.



**Figure 1.** The streaming of the teacher's PC-screen to the learners.

The learners got a number of weekly *assignments*. The aim of the assignments was two-fold: First, they should afford individual knowledge construction concerning the programming language Java, as well as provide practical and hands-on skills on e.g. the execution of program codes. Second, they should maintain awareness information to the teacher regarding the learner's knowing, development and progression.

## Research approach

To examine the social interaction patterns that developed in the online apprenticeship-motivated learning environment, two primary research activities were conducted. The first was an exploratory case study (Yin, 2003) of IOOP during the fall 2003 semester, conducted by the second and third author. The second was a design experiment (Brown, 1992) conducted during the spring 2004 semester of IOOP, aimed at further exploring critical issues identified in the case study. The first and third author designed the experiment, and the first author carried it out. The three authors have analyzed data from the design experiment jointly.

## Case study

The aim of the case study was to examine online apprenticeship learning in a *real delivery situation*. The course was a part of the MS program in Software Construction with 22 participants. Most of the learners were committed to a daily work situation for which the course content was significant. All the learners had programmed in their daily work, although not necessarily using an object-oriented approach. The course started with a weekend seminar (on campus) and concluded with the final exam five months later.

Since the online meetings constituted a central mechanism for operationalizing the apprenticeship approach (see the section 'Results from the case study'), they came to be the basis of our analysis. The data was gathered by *online observation* of the online meetings, where the researchers were present in the shared space, but did not participate in the online interactions. During the course, 14 online meetings took place. The meetings started at 8:30 p.m. on Thursday nights, typically lasting for 1½ hour. Furthermore, recordings of the audio- and video streams from the teacher and logs of the corresponding Instant Messaging (IM) sessions constituted the basis for *interaction analysis* (Jordan & Henderson, 1995). This latter approach provided us with the possibility to examine to what extent the social interactions influenced collective meaning-making and knowledge constructions amongst the learners, and how the technological artefacts were used to support certain actions and the social interactions between learners and teacher. Another important aspect is that the experiences of the learners become visible and documented in the "temporal orderliness and project ability of the events they construct" (Jordan & Henderson, 1995, p. 61).

*In-depth interviews* with nine learners were carried out just after the final exam. The interviews lasted approx. 30 minutes each. Two interviews were conducted with the teacher: a one-hour interview at the outset of the semester, and a 90-minute interview at the end of the course. The learners' and the teacher's talks as well as the observation notes constituted rich supplements to the analysis of selected transcripts of the recordings.

## **Design experiment**

A design experiment was conducted as a follow-up activity of the case study, and took place during week 6 of the 15-week course in the spring semester 2004. The aim was to explore critical issues identified during the case study, with a particular focus on learners' collaboration. Design experiments differ in interesting ways from both laboratory experiments and naturalistic investigations (Brown, 1992). Ludvigsen & Mørch (2003) put it very clearly this way: "Design experiments can be seen as intervention in the educational practice since the researchers, in collaboration with teachers, try to change the way the students work. These shifts often presuppose a change in participation structures and how agency and division of labour are distributed between teacher and the students" (Ibid, p. 67).

The delivery situation in spring semester of 2004 was close to identical with the delivery situation in fall semester 2003 (presented in the section on Course considerations): The design, content and objectives, and the learners were part-time learners committed to a daily work situation. However, the course was delivered as part of the MS programs in *ICT and organization or multimedia*. Another major difference was that a new teacher replaced the one from the preceding semester. Twelve learners attended this semester of the online course. The primary motive for many of the learners was to get an insight into how a programmer works and not necessarily to become a programmer themselves. Ten learners participated in the experiment, formed into three groups: Group 1 through 3. Groups 1 and 2 were guided by the fall 03 teacher, group 3 by one of the (two) original course designers. The groups were formed from the beginning of the course, based on home address in order to ease physical meetings among the group members. All the groups had collaborated (in co-located settings) before the experiment.

All groups had the same task of modifying and extending a program that could keep a schedule of marriage reservations for a church. This problem was divided into four sub-tasks to cover different parts of object-orientation and the programming process.



Due to the focus on the social interaction and collaboration amongst the learners, it became vital to study the learners' creation of joint understanding through a collaboration tool. The collaboration tool Centra includes functionalities such as a (shared) whiteboard, text-based chat, audio facilities, and application sharing (Centra, 2004; Estes, 2004). As in the case study, the online activities were recorded for later interaction analysis. Group interviews, also administered through Centra, were conducted immediately after the final online session.

In the following, we will describe, analyse and discuss social interaction patterns arising when taking apprenticeship learning online using the many sources of information.

## **Results from the case study**

Other research (Fjuk & Berge, *forthcoming*) based on online observations and interaction analysis of the online meetings shows that the learner activity (in the textual IM conference) was modest. The teacher made deliberate attempts at inspiring engagement and social interactions amongst the learners. This was e.g. achieved by taking pauses to ask for suggestions and reflections on a problem. Overall, the teacher's efforts to stimulate the learners to become more active during the online meetings were only moderately successful. This is in line with the findings reported by Levin & Waugh (1998) on teaching teleapprenticeships. Here the authors found that the benefit of online interactions was not enough to overcome the costs, since it was easier meet face-to-face for communicating. However, the learners had reduced possibilities to meet physically. In the IOOP case, one complicating factor in the interaction between the teacher and the learners was the delay in the video/audio stream of about 30 seconds, while the IM was close to instantaneous. Even though the teacher responded to an IM entry immediately using the video stream, the learners did not receive the response until approximately 30 seconds later. It should be noted that both the teacher and the learners adjusted to this constraint during the course. Other constraints that were brought up were problems due to typing speed or a reluctance to "speak in public". Another issue, raised by a learner in our interview, was of a more technical nature:

"Well, sometimes when [ the teacher ] asked a question, I needed to see a part of the code that was not visible on his screen. It was hard to answer the question without scrolling his code window".

Despite the issues brought up here, both the teacher and most of the learners interviewed stated that all-in-all they found the technical solution to be rather unproblematic.

The interaction analysis of the transcripts (from the online meetings) shows that the online meetings did not develop into a professional discussion amongst the learners. Hence, the interaction analysis in itself did not provide confirmation regarding collective development of understanding and individual learning effect of social interactions (Berge and Fjuk, *forthcoming*).

The interviews with the learners, however, indicate an individual learning effect of taking part in the online meetings. Several of them emphasized that they have constructed new conceptual knowledge on object-orientation that was immediately applicable for their daily professional practice. Thus, this part of online apprenticeship seems to have been reasonably successful in the sense that the teacher's ways of showing (modelling) the processes of programming and verbal reflections on these actions were considered vital by the learners. In the interview after the final exam, one of the learners articulated his view on this in the following way:

"[ the teacher ] has a basic idea about what he shows and teaches (...) his way of articulating this is important (...) [ the teacher ]'s way of showing the themes has definitely been important for a totally new experience on what object-orientation is"

The modest social interactions amongst the learners in the online meetings contradicted the teacher's needs for awareness information on the individual learner's knowing and progress in order to scaffold them. Arguably, the weekly assignments were also important instruments in this respect (emphasized by learners in interviews). Still, they are limited to afford evaluation of the *final products* or solutions of the learner's work. These solutions can only shed light on the learner's problem solving *processes* to a modest degree. To be able to

scaffold and help the learner's reflection on the learners' programming process the teacher stated the following need in the second interview:

"If I could participate in problem solving together with the learners, I would get a much better feel for – in detail – what issues that are problematic for them".

Concluding, the case study has raised some issues that we have found important to investigate in understanding of the master-role. The first issue concerns conditions for productive learning through dialogues and collective activities so that the teacher not solely carries out the master-role. The second issue concerns conditions connected to the teacher's participation and legitimating roles in order to qualify the master's possibility for scaffolding and initiate reflections. These issues were brought further into the design experiment.

## **Results from the design experiment**

The experiment was conducted in two phases: In the *first phase* each group was given a short introduction to the functionalities of the collaborative tool Centra. The group was expected to create a shared understanding of the pre-defined problem, and agree on a division of the work amongst them. The teacher's role was to take part in the dialogue by asking critical questions and by guiding the learners to a common understanding. In the *second phase* - the actual problem solving process - the teacher's role was to legitimize the learners' actions and to scaffold when the learners encountered breakdowns in their collaboration. The teacher should also initiate reflections by discussing the learners' solutions as compared to how a professional programmer typically would solve such a problem.

### **The patterns of social interactions**

In what follows we show and discuss the social interactions that developed for each of the three groups. Extracts from transcripts connected to the collaborative solving of the first sub-task are selected. The objective of this task was to create a set of so-called object diagrams. An object diagram serves as a visual description of the state of a program code at a given time of execution. The

problem addresses a central issue in object-orientation: the distinction between classes and objects. The task has one correct solution. The analysis indicates that each group developed different social interaction patterns during their problem-solving process.

### Group 1: Collective reflections on an individual contribution

During the first session, the group agreed that they should make an outline of a solution individually before session 2. At the outset of session 2, the group spent approximately four minutes on agreeing on a strategy to approach the problem. Then Kristy displayed her proposal, shown in figure 2(a). The following dialogue ensued<sup>2</sup>:

#### Extract 1. Collective reflections

1	Kristy	I was in a little doubt about if those methods should be included in the object diagram. There aren't many examples in the book. What do you think?
2		(6,0)
3	Thomas	I think the same as you, there are really not many examples of how one should make such object diagrams. Ehh, I have actually not seen any where methods, relations, or such are included before. So, I am in doubt as to whether if, if they should be included – when I have seen them, there are usually only the four objects one see, eh, by themselves.
4		(5.0)
5	Kristy	The reason I have included them is the way the task is formulated. That one ... first in line 15 one should draw an object diagram, and again one should draw an object diagram at line 18 and line 21, and if one shouldn't include the relations, then it would be only the four objects and therefore no reason to draw the object diagram several times.
6		(12.0)
7	Thomas	No, that is correct. But then one should, as I see it, draw four object diagrams, where the first object diagram, that is only the four, ehh, independent objects, and then you get the relation on, one has the

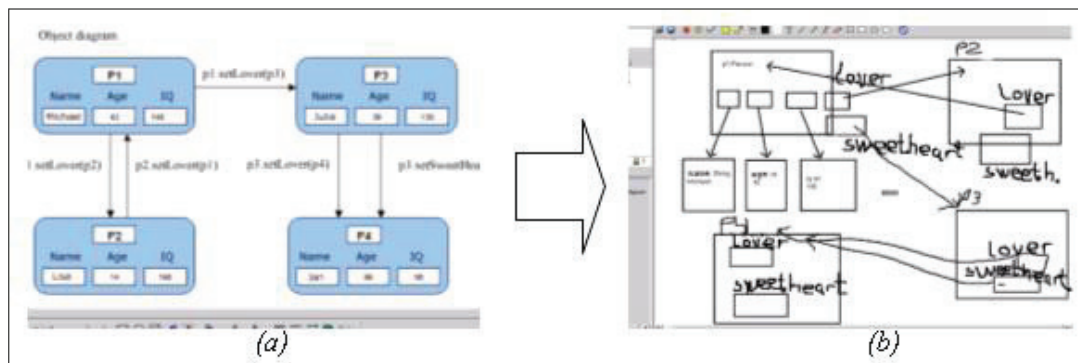
<sup>2</sup> The text in all the transcripts and diagrams is translated from Danish by the authors.

		relation from the first, P1 loves P2, and, and P2 to P1, then one takes that diagram and ((inaudible)).
8		(8.0)
9	Kristy	You might very well be right, Thomas. Uhm, it might be because this example, the driver class, seems a bit, ehh, what is it called, it seems a bit much to make four so simple diagrams instead of creating one all together. It is still easy to get an overview.
10		(6.0)
11	Thomas	Neil, what do you think about this?
12		(5.0)
13	Neil	Yees. At the outset, it seems, it looks very useful, it gives a structure, a very good structure. Where I am in doubt, that is if it follows the rules as such, but there is no doubt that, as I know the task, that it is a picture of, of the issue
14		(5.0)
15	Kristy	Should we ask Teacher?

In line 1, Kristy starts by pointing to an issue of uncertainty for her. She opens for discussion by inviting comments from the other learners. The 6-second pause indicated in line 2 is to some extent accounted for by a feature of Centra, which is that only one participant can speak at a time. The transfer of control of "microphone ownership" takes 4-5 seconds. In line 3 through 9, Kristy and Thomas seem to establish an agreement that relations between objects should be represented, but they are unsure about how. Then, Thomas invites Neil to offer his opinion. Neil, who has not participated in the discussion so far, seems to agree that the relations should be represented, but expresses concern about notation. At this point, Kristy suggests that they ask the teacher for guidance.

One characteristic of the extract shown in extract 1 is that the learners offer their understanding of the topic, and that they to some extent build on each other's utterances towards establishing a shared understanding. The point of departure for the discussion was Kristy's somewhat incorrect proposal (shown in figure 2(a)). This was, at the outset, displayed in the shared workspace for approx. ten minutes, and then for approx. five minutes later on. While the diagram was displayed, the learners repeatedly referred to it; one example is found in line 7, where Thomas refers to P1 and P2. Serving as both a means

for supporting Kristy's initial understanding and as a common frame of reference during the following discussion, the diagram seemed to have a central position in the collaborative endeavour. After 20 minutes, the group chose to make a new diagram from scratch using the shared whiteboard. During the next 20 minutes, the group used this as a fundamental means, and arrived at an almost correct solution (figure 2(b)).



**Figure 2.** The initial solution (a) made by one of the learners and the final solution (b) made in collaboration.

### Group 2: Joint solving of the problem through teacher legitimated actions

During the first session, group 2 agreed that everybody should individually reflect upon how to approach the problem and ideally make an outline of a solution. However, none of the learners had prepared a solution for the second session. The group spent the first 14 minutes to discuss what tools and approaches to use to solve the problem. The teacher intervened in the discussion, suggesting that they use the shared whiteboard. Then the following social interactions developed:

#### **Extract 2.** Joint problem solving through teacher legitimated actions

- |   |         |  |
|---|---------|--|
| 1 | Karen   | Is there any one of you that have a bid for how to start, or should we just start to draw, or what?                                    |
| 2 |         | (8)  |
| 3 | Mary    | I can try start try drawing, and we can see if it turns out very wrong ((laughter))  |
| 4 |         | (6)  |
| 5 | Teacher | Good. It is important, Mary, while you draw that you activate that lock, and tell us about what you are doing. Because, otherwise, the |

		rest of us does not have the possibility to say something or to comment, or something else. Moreover, you others can raise your hand and say, ... if you would like to speak.
6		(8)
7	Mary	OK, Ehmm. I would like to, I will try and see if I can draw an object diagram that, based on the class Person, that of course is described in the task, but I will do it with reference to page 53 in the book where there is something about object diagrams, because that is one of the things, I think, I am confused about. I reckon I will get some comments as I go along.
8	Mary	((Draws a rectangle))
9	Mary	The first thing I would like to try to make is this very nice rectangle. Moreover, it is meant to illustrate the new object.
10		(7)
11	Mary	And it should have an... How does one write, Teacher?

After the opening comment from Karen, Mary takes on the responsibility of drawing the object diagram. The latter part of her statement in line 3 indicates that she is quite defensive about her ability to make a correct solution. In line 5, we see that the teacher intervenes with advice about how the group can work, including instructions about the functionality in Centra (microphone "lock" and "raise your hand"). Again, in line 7, Mary states that she is uncertain about how to draw object diagrams, and she invites comments from the others. She proceeds by drawing a rectangle, and then asks the teacher a question about functionality in Centra.

This extract indicates a characteristic issue of the social interactions in group 2. The learners were open with regard to the correctness of their suggestions, and they frequently sought to legitimize their actions with their peers or the teacher. Moreover, the group proceeded hesitatingly, often not making much progress until the teacher intervened. The group spent a total of 56 minutes to arrive at an outline of an object diagram that was close to correct (figure 3).



**Figure 3.** The final solution made in collaboration.

### Group 3: Monologue

During the first four minutes of the session, the teacher explains how to use Centra and suggests a form where the learners take turns presenting their solutions. He also encourages comments or questions from the other learners during these presentations, and informs that he will take a passive role. Ray volunteers to present his solution first and displays the diagram shown in figure 4(a). Then the following dialogue took place:

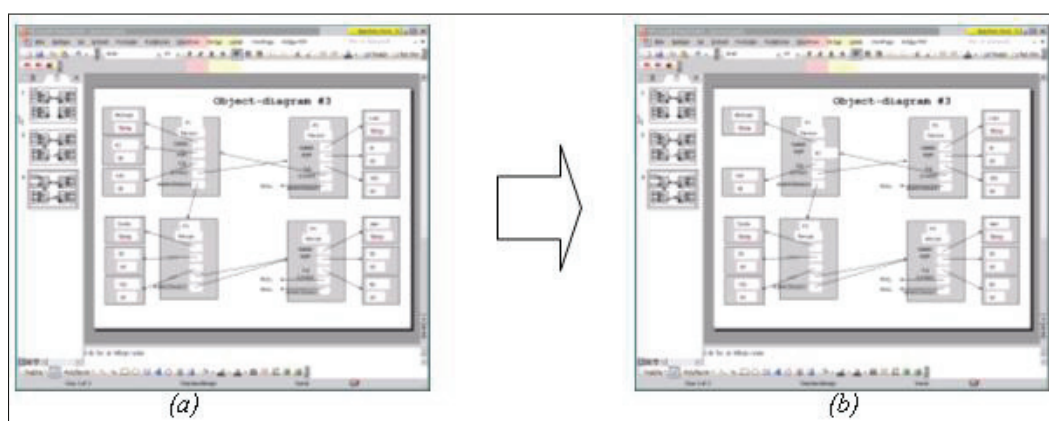
#### **Extract 3.** Monologue

- |   |       |  |
|---|-------|--|
| 1 | Ray   | What I have done here, first, is of course to set the state that the objects have where it is stated that we should draw the object diagram  |
| 2 |       | (12)   |
| 3 | Ray   | Is there anyone who has any comments to this first one?  |
| 4 |       | (2)  |
| 5 | Peter | Yes, you sent this one to me yesterday, Ray, and I have looked through it. What I was thinking, I'm a bit puzzled that you have taken the regular types, string and int, and drawn them as, what is it called, independent objects. I know that string is an independent object, eh, but I am actually in doubt whether int is an independent object. But would one usually do that in an object diagram, could we discuss that? |
| 6 |       | (5)  |
| 7 | Ray   | I don't know. It is possible that one should bring them inside, so that  |



one can see what the value is. Maybe you could comment on that, Teacher?

Ray sets out with a high-level comment on his diagram (see figure 4(a)). His use of the term "of course" could indicate that he is confident regarding the correctness of his proposal. However, after a 12-second lapse, he opens up for discussion by requesting comments. The diagram is almost correct; it is actually very similar to group 2's final solution. Peter directs the attention to the only error in the diagram. In line 7, Ray suggests the correct solution and asks the teacher for comments. During the next 10 minutes, Ray, Peter and the teacher discuss Ray's three object diagrams at an advanced level.



**Figure 4.** The initial solution (a) made by one of the learners and the final solution modified by another learner (b) in the shared application.

In this period, two of the learners (Lea and Judith) did not take part in the social interactions. Then, after Ray has suggested that the group move on to the next task, the teacher asks if Judith and Lea have any comments. Lea shows her prepared solution, and the social interactions for the remaining 30 minutes were based on her suggestion.

The dominating role of the teacher is one striking feature of the interaction in group 3. An examination of turn-taking shows that the teacher controlled the microphone more than half of the total time. In comparison, the other teacher was in control for 18 % and 23 % of group 1 and 2, respectively. Table 1 shows how much of the time each participant in group 3 either spoke or was active in terms of a shared tool (e.g. the whiteboard), and how many times during the session each learner was "in control" of the microphone, the shared

application, or both. In addition, the table shows pauses, meaning time spans where there were no actions in the shared space.

**Table 1.** Turn-taking in group 3

Participant	Total time	% of time	Number of turns
Ray	03:29	7 %	21
Peter	03:50	8 %	10
Judith	01:09	2 %	7
Lea	03:10	7 %	17
Teacher	25:47	53 %	36
Pause	11:00	23 %	63
<b>Total</b>	<b>48:25</b>	<b>100 %</b>	<b>154</b>

This strong presence is in contrast to the teacher's stated intention, as described at the start of this section. The discussions departed from the learners' understanding as expressed in their object diagrams, questions and comments, and the teachers' contributions were of a lecture-oriented character. It became apparent early on in the session that a monologue-like interaction was the pattern characterizing this group. Although the group arrived at a correct solution early on, they did not explicitly agree on one common solution.

## Summary and conclusion

This research was aimed at examining the social interaction patterns for online learning environments of which the design is inspired by ideas of apprenticeship learning. The first part of the embedded study was a case study conducted in fall semester 2003. The second part of the study was a design experiment conducted in spring semester 2004, aimed at exploring critical issues found in the delivery situation of the previous semester. Both these studies identified some issues that are interesting for further pedagogical designs of online learning environments.

The online course design was motivated by ideas found in apprenticeship learning and included a dynamic balance between the following: ICT Support for information sharing and joint creation of meaning amongst the learners; Online support for the teacher's reflection in action in terms of both natural

and scientific language, as well as support for showing and legitimating the creative and analytical process of programming; Support for awareness information on the learner's knowing and progression. In the original online course design, the weekly online meetings constituted the primary instrument for maintaining this balance. However, the case study shows a modest level of social interaction amongst the learners in these meetings. A fundamental awareness instrument for the teacher to achieve insights into the learner's knowing and progress was thus almost absent. Therefore, it was difficult for the teacher to legitimate the knowledge of the learners. Disregarding the IM component, the video and audio streaming technologies used (Windows Media Player) have a functionality that implicitly supports an information transformation style, with no opportunities for feedback from the audience. This functionality proved to be well suited for practicing the important aim of showing the learners how a professional programmer (the teacher) reflects and reasons in the creative process of programming. The interviews also indicate that the learners did get a deeper understanding of observing the teacher's actions and reflections. Hence, this particular idea from apprenticeship learning seems to have been successfully transformed to the online environment. Outlined from the case study, the interaction pattern predominant in the online meetings was that of traditional lecturing. The critical condition in this respect seems to be *the teacher's awareness on the learners' knowing*. This condition can be maintained through different activities. An example is meta-communication in terms of questions, pauses, and exercises.

The intervention study provided additional insights. Our interaction analysis suggests that an individual learner's prepared solution (before the group session) shaped the group's interaction patterns. Prepared proposals thus seem to be a critical condition for successful collective knowledge construction. The analysis, however, also indicates that a pre-prepared suggestion in itself should not be considered in isolation. In addition, how its creator articulates the suggestion might be of importance in an online setting. In group 1, the learner who presented her suggestion made clear the challenge she met in solving the problem, and sought other alternatives and explanations from the co-learners. In this way, the presenter invited collective reflection upon the pre-prepared suggestion. This initial social interaction pattern – *Collective re-*

*flexion on an individual contribution* – characterizes the group throughout their online collaboration, and resulted in a new and more correct solution to the problem. In contrast to group 1's pattern of social interaction, group 3 developed a *monologue* pattern. In this group, the presentation style was more like a lecture on a correct solution. In contrast to group 1 and group 2, we understand this pattern of collective activity as not very productive regarding the development of collective reflection upon the shared artefact. Group 2 started out without a proposal for an object diagram. The group proceeded hesitatingly, often depending on the teacher's scaffolding for moving on. We propose that the group's interaction pattern was shaped by the lack of a common reference manifested in a draft object diagram.

Furthermore, the teacher seemed to have an important role in guiding the learners to a joint and correct solution. The learners considered these scaffolding actions important. This was most apparent in groups 1 and 2, in contrast to group 3, where the teacher engaged in a more traditional lecturing role. In groups 1 and 2, however, the teacher extensively performed meta-communicative actions. These communicative actions encouraged the individual learners to articulate and to make their interpretations and thinking explicit, facilitating for construction of a deeper individual understanding. They also provided means for the teacher to gain insights into the learners' understanding as well as guiding the process of programming and conceptual understanding – rather than the traditional way of commenting on the final solution only.

The findings from the study are not new regarding theories on learning and human development. It is in line with well-known learning theories that emphasize the mutually consisting processes of individual and collective activity (Engeström, 1987; Lave & Wenger, 1991; Kaptelinin & Cole, 2002). As Kaptelinin and Cole (2002) put it: "(...), not only does collaboration between the learner and other people change some pre-existing individual phenomenon, but also directs and shapes both the general orientation and specific content of individual development" (Ibid., p. 304). The interaction analysis indicates, however, the importance of deliberately incorporating this duality in an *online learning design*, by organising for individual activities (preparation of sugges-

tions for solutions) and for collaborative activities through open and peer legitimating actions. Others also discuss this critical issue. For example, Krange and Fjuk (2004) emphasise the opportunity of changing between closeness to collaborative peers through e.g. shared ICT-application and distance to peers in order to articulate thoughts through reflection.

Based on our study, we suggest that the primary and critical condition is a *pre-prepared suggestion for a solution*. Such a shared artefact constitutes an important communicative instrument for establishing productive collective activities online. However, this condition's success is dependent on an open and legitimating social interaction pattern to reduce the chance of developing a monologue pattern. We advise that future online course design carefully integrate this condition and its requirement. In addition, attention to supporting the teacher's awareness information regarding the learners' level of knowledge and progression is critical when approaching online apprenticeship learning environments. A certain level of meta-communications in terms of questions, pauses, and exercises seem to be a requirement in this respect.

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# Appendix D

## Paper IV

Berge, O. and Fjuk, A. (2006)

*Understanding the Roles of Online Meetings in a Net-Based Course*

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# Understanding the roles of online meetings in a net-based course

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## Abstract

It is argued elsewhere that online learning environments constitute new conditions for carrying out collaborative learning activities. This article explores the roles of a series of online meetings in such an environment. The online meetings are arranged as part of a net-based course on object-oriented programming, and constitute a recurring shared experience for the participants throughout the semester. Through an activity theoretical analysis, we find that the meetings mediate the learners' actions towards the construction and maintenance of a community of practice. Our finding has implications for the standardization of digital learning resources. This is an issue that will challenge designers of research-oriented learning environments, should they attempt to move their systems into wider adoption. We suggest that an awareness of the internal systemic connections among the components of the course design we studied is of importance when considering redesign, with respect to the reuse and standardization of learning resources.

## Keywords

activity theory, apprenticeship, case study, groupware, networked learning, standardization.

## Introduction

The background for the research in this article is the discussion of the standardization of learning technology and digital learning resources. The proliferation of ICT in formal education institutions is followed by a corresponding interest in improving the cost-efficiency in developing and deploying such resources (e.g. McGreal 2004). This is approached through facilitation for the reuse of learning resources, in the form of standardized reusable learning objects (Wiley 2000).

Our research is concerned with ICT-mediated, distributed learning environments. These have their roots in early efforts within distance education, where ICT was used to enhance student communication and col-

laboration across time and place (e.g. Harasim 1990; Kaye 1992). More recently, a number of innovative, research-oriented learning environments have been developed. These include environments such as CSILE, enabling knowledge-building discourse (Scardamalia & Bereiter 1994), WISE, facilitating inquiry-based science (Slotta 2002), Fle, designed to support learner- and group-centered work that concentrates on knowledge artefacts and design (Leinonen *et al.* 2002); Synergieia, supporting collaborative knowledge-building in classrooms (Stahl 2004), and a collaborative learning system backed by wirelessly connected handheld computers (Cortez *et al.* 2005).

Developers of such research-oriented systems are likely to meet the challenge of standardization if they attempt to move their innovations into wider adoption. We contribute to the discussion of deploying reusable learning resources by exploring the complexity of ICT-mediated learning environments. We contend that the transformation of digital learning resources into

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reusable learning objects might have a profound impact on the communicative conditions of the learning situations in which they are used. Recent research has indicated that the use of learning resources is situated with respect to various interconnected aspects of the learning situations. These can include the characteristics of the knowledge domain, the learning objectives, the features of the ICTs used to mediate learning activities, the pedagogical approach, the target group, and institutional practices (Fjuk & Dirckinck-Holmfeld 1997; Fjuk & Ludvigsen 2001; Wasson & Ludvigsen 2003). We propose that the situated use of learning resources within this complexity should be understood when considering their transformation into reusable learning objects. Specifically, we analyse the roles of one resource – online meetings – in a net-based course on introductory object-oriented programming.

We start with a description of this course in terms of a brief introduction to the subject domain and a description of the course design. This is followed by a section describing our research method, including our empirical research approach and analytical framework, Cultural Historical Activity Theory. Our data are presented and analysed in the section ‘The online meetings’, followed by a discussion of our findings. This article is concluded with a summary and discussion of the implications of our research results.

### Introduction to object-oriented programming

Our study was carried out on the course ‘Introduction to object-oriented programming’ (IOOP) at the University of Aarhus, Denmark. This university-level course has been offered as a campus-based course for more than a decade. We studied it the second time it was carried out as a net-based course. This organization was chosen to accommodate the target group: adult part-time students all across Denmark.

The knowledge domain, object orientation, denotes a specific approach to software construction. It is a way of understanding complex phenomena through the analysis and design of executable computer programs (Madsen *et al.* 1993). In line with the Scandinavian heritage of object orientation, the principal focus of the IOOP course is a systematic and conceptual way of modeling (Knudsen & Madsen 1990). That is, the emphasis is on constructs that describe

concepts and phenomena, rather than on instructions for computers or on the management of program descriptions. Given this view, a central objective is to learn systematic ways of implementing general models and obtain a deeper understanding of *programming processes*. Hence, it is considered important that the students achieve hands-on experience and develop practical skills, as well as abstract knowledge on the basic object-oriented concepts.

Driven by the needs of the target group and the learning objectives of the course, the pedagogical approach in IOOP was informed by facets of apprenticeship learning (e.g. Nielsen & Kvale 1997). This pedagogical approach focuses on the learner’s participation in a community of practitioners, where the teacher or a more experienced peer legitimizes the skills and knowledge of the individual learner. Mastery does not reside in the teacher alone, but in the community (of which the teacher is a part) and on the structuring of the community’s learning resources. Furthermore, the apprenticeship-inspired approach requires good communicative conditions for reflection-in-action and for making the actions of the teacher visible and a source of identification (Nielsen & Kvale 1997). The teacher should be allowed to articulate and think aloud in terms of both natural and scientific language, as well as in showing the pragmatics of programming.

### IOOP course design

A series of *online meetings* was arranged for implementing the principles described in the previous section; they were usually conducted once a week. The intention of the course design was to treat topics based on the individual student’s experiences in solving the weekly assignment. This approach denotes a particular mode of engagement and student control, and at the same time the teacher legitimates and shows how programming/modelling processes associated with the weekly problem areas can be approached. The online meetings were mediated by real-time video streaming of a part of the teacher’s PC monitor. Through Windows Media Player, the students could see the teacher’s PowerPoint presentations and text documents, his actions in various programming and modelling applications, etc. There was a corresponding audio stream relaying the teacher’s voice. In order to support

interactions among the participants, a text-based Instant Messaging (IM) conference was set up in conjunction with the real-time audio and video streams. All participants used the *Yahoo! Messenger* application for IM. The IM sessions were set up as private conferences, where the students were invited to join at the outset of the meetings. IM entries from all participants were displayed in the main window of the application, preceded by a time stamp, and the contributor's nickname. The list of participants in the conference was displayed in a secondary window. A teaching assistant also participated in the meetings; her role was to set up and maintain the IM conference, and conduct private IM sessions with the teacher (to provide reminders, for example) and with students experiencing technical problems. The video and audio streams (denoted 'video stream' in the following) from the meetings were captured, indexed with time stamps according to topics, and made available to the students on the course website.

The students were given 12 mandatory assignments, with one given in most weeks. A prerequisite for entering the exam was that the student had passed at least 80 % of the assignments. The assignments were considered a fundamental means of interaction between the students and the teacher, and thus for legitimizing the student's actions towards the problems. On the organizational side, one important mechanism for supporting social interactions among the students was the weekend seminars. During the course, the students met physically for three 2-day seminars. One central reason behind these weekend seminars was stimulating collaborative activities, while the students worked distributed.

## Method

The empirical research was carried out as a case study on the IOOP course during the fall semester of 2003. The course started with a weekend seminar, where the participants met on campus. During the course, two additional weekend seminars were conducted and 14 online meetings took place. The data were gathered by observation of online activities, including 10 of the online meetings, and postings on the discussion boards. Recordings of the video streams, logs of the corresponding IM sessions, and observation notes comprise data from the online meetings. Documents

and learning resources available on the course website were also gathered for analysis. In-depth audio-recorded interviews with nine students and the teaching assistant were carried out just after the final exam, with each lasting approximately 30 min. A 1-h interview with the teacher was conducted during the first weekend seminar, and a 90-min interview was conducted at the end of the course.

Eighteen of the 22 students who registered for the course in the fall 2004 semester completed it. Three of the students were female, and the ages of the students ranged from early 30s to early 60s, with the majority being in their mid-to-late 30s. Most students held full-time jobs during the course, many as computer programmers. Also taking part was one teacher – who was also one of the two course designers – and one teaching assistant. All students were informed by the teacher of the researchers' presence at the outset of the semester, including an explanation of the aim and scope of the observations. All the informants signed an informed consent document during the study.

At the outset, the research project was an explorative study, aimed at understanding the new communicative conditions of online learning environments. Using Cultural–Historical Activity Theory as our analytical framework, the online meetings came out as interesting in this respect. Those meetings did not play out as intended in the course design, but observations and interviews indicated that the students regarded them as important learning resources. Therefore, the emphasis of our analysis is on these meetings. The primary material used in this analysis is the data from the meetings, together with the interviews. From the approximately 12 h of meeting recordings, we have selected a 3-min segment for presentation in this article. This segment represents an example of a typical interaction pattern in situations where the interaction was initiated by a subject-domain question from the teacher.

The logs from the IM application constitute a complete record of all the entries made by the participants in the meetings we observed. These entries have been coded by topic. The purpose of this categorization was to get an overview of what kind of issues were discussed in the IM sessions. The categories were constructed by a process whereby we looked for concepts that could describe what kind of issues the entries addressed. The selection of cate-

gories was also informed by theory on computer-mediated communication, from the field of distance education. The categories 'social', 'administrative', and 'object orientation' (i.e. the subject matter) are taken from Fjuk (1998), and 'moderation' from Feenberg (1989). One IM entry is treated as one unit in the coding scheme, and the entries are labelled with only one code. Some entries might be interpreted as addressing multiple issues, but these are coded according to what we understood to be the main meaning of the entry. Our coding scheme is a rather coarse one, but we found it productive in terms of our analytical process.

The extracts from interviews with students and faculty presented in this article are chosen to inform the analysis with the participants' subjective accounts of particular aspects of the online meetings.

### Analytical framework

Cultural-Historical Activity Theory (Engeström 1987; Engeström *et al.* 1999) is founded on a sociocultural perspective of human development (Leontiev 1978; Vygotsky 1978, 1986; Wertsch 1991). The basic unit of analysis in Activity Theory is the activity, and activities are analytically isolated by the motive that elicits them (Leontiev 1978). Activities are driven by a motive: 'An activity is a form of doing directed to an object, and activities are distinguished from each other according to their objects. Transforming the object into an outcome motivates the existence of an activity' (Kuutti 1996, p. 27). The minimal meaningful context for understanding individual actions is the activity; in an activity system, proposed by Engeström (1987), the subject's actions towards the object of the activity is mediated by both *instruments* (artefacts) and the people who share the same object, the *community*. The subject's relation to the community is mediated by rules, and the relation between the community and the object is mediated by division of labour.

Our analysis is founded on Engeström's systemic model of an activity. We set out by searching for areas of tension<sup>1</sup> in the processes we observed. These areas of tension can appear within the elements of the activity system, between them, between different activities, or between different developmental phases of an

activity (Kuutti 1996). Tensions materialize as breakdowns, clashes, or disruptions in the activities. Guided by the identified tensions, we studied moment-by-moment interactions with the help of interaction analysis. As part of our analysis, we created categories from the data material (i.e. the IM entries from the online meetings) and coded the material according to these categories. Episodes of these interactions were selected for more detailed analysis. To gain an understanding of the systemic whole of the activity, our analysis iterated between studies of the individuals' actions carried out in these interactions and the context in which they were carried out.

As described, an initial analysis of the IOOP course directed our attention towards the online meetings. This analysis is presented in the following.

### The online meetings

The analysis of the online meetings starts with an examination of student activity from the perspective of the teachers, presented in the next section. This is followed by an exploration of possible accounts for low student activity. The analysis part of this article is concluded by a study of student participation.

### Student activity

As discussed in the section describing IOOP, one intended role of the online meetings was to contribute to the collaborative aspect of the apprenticeship-inspired pedagogical approach. The main topic in the second interview with the teacher, carried out after the completion of the semester, was his experiences from this instance of the course. We asked if he had made any changes in the design of the course from the previous semester. He brought forth modifications to the online meetings as one important change: 'I tried to experiment with making it [the online meetings] more interactive, by to a larger degree asking questions and introducing tasks – although without much success – as we went along. [. . .] The interaction, or dialogue, is one thing that I have worked on this semester'.<sup>2</sup> The other change he highlighted in the interview was what he called 'making the online meetings more goal-or-

<sup>1</sup>The term 'contradiction' is used by Engeström (1987).

<sup>2</sup>All direct quotes are translated from the original Danish version by the authors.



iented'. In the previous semester, one part of the meeting was about presenting how students should approach the assignment (i.e. interpreting the problem description and choosing strategies for solving the problem). Another part was about the teacher making general comments on the students' solutions to the previous week's assignments. He decided to leave these two parts out of the meetings. Instead, he recorded these two parts before the meetings and made them available to the students as pre-produced learning resources. 'There were some parts that were one-way anyway', the teacher said, 'so they could just as well be offered asynchronously. And then we could use the synchronous event for dialogue'.

He proceeded by commenting on the outcome of his design intentions: 'That this has not worked out, to any extent, is another side of the story. It is not like there have been questions to ... 'what you just said, how come ...' and so on. But that was the intention, anyway'. He also made this point strongly later on in the interview, as a part of his response to a request for him to describe his perspective on the ideal form of the course: 'And then that the synchronous activities, that they come to be about that it is important that we are together, or are there at the same time. In relation to, well, some times they [the students] could just as well let it be, they might as well [join the chat and then] watch the news. Then they could view it [the recorded meeting] afterwards, because there was no interaction whatsoever, or discussion, or anything else'.

The teaching assistant expressed a view on student activity during the online meetings similar to that of the teacher. When asked in our interview if she could see any clear potential for improvement with regard to the tools used in the course, she responded: 'There are some conditions that could have been better. About the text-based chat, it really takes a lot before people [the students] gets active. It is like [the teacher] puts it, like speaking out into the blue'.

Both the teacher and the teaching assistant have stated that student activity in the online meetings was lower than they had hoped for. In the course design, the IM conference was intended to mediate the students' actions towards the other participants. A measure of the level of student activity, as perceived by the teacher and the teaching assistant, is therefore the number of entries in the IM conference. In the 10 meetings observed by us, there were a total of 768

entries. Out of these, students contributed 428, the teacher made 292, and the teaching assistant submitted 48 entries to the shared IM conferences. In order to provide an impression of the level of intensity of the IM interaction, we provide an example of how the entries were distributed over time in one meeting. Figure 1 shows the number of IM entries (vertical axis) for each 1-min time segment (horizontal axis) of the seventh online meeting, which is chosen as a typical example. The figure shows the highest IM activity occurred during the first 5 min, and towards the conclusion of the meeting. It also indicates that most of the IM activity was grouped in four 'clusters' along the time axis.

#### Accounts for low student activity

According to the teachers' accounts, the figures above represent low student activity. What could be the reasons for sparse interaction during meetings? During our observation of the meetings, we noted a feature of the combination of the text-based IM and the video stream that might be problematic. The transcript in Table 1 shows an extract of interactions that developed approximately 40 min into the 12th meeting. The audio from the video stream is translated and transcribed in the fourth column. The text in the fifth column is a translation of the entries from the IM logs.

The teacher explains the Model-View-Control pattern, which is a commonly used and powerful architecture for constructing graphical user interfaces. A graphical representation (a UML class diagram) of the pattern is visible on the teacher's screen. In line 1, the teacher writes a question about the relation between two classes in the diagram. This is a reformulation of a question he raised 2 min earlier. His comment in line 2 refers to a reply to this first question. Barbara's reply to the question, in line 3, is submitted almost simultaneously with the teacher's prompt for replies in line 4. Jack suggests another answer to the question in line 5. The teacher acknowledges Barbara's proposal in line 6. There is a delay on the video stream of about 20–30 s, while the IM is close to instantaneous. Even though the teacher comments on Barbara's entry at once, the students hear this comment 30 s later.

The extract shows part of a typical Initiation-Response-Follow-up (IRF) structure often found in classroom settings (Wells 1993). The time delay re-

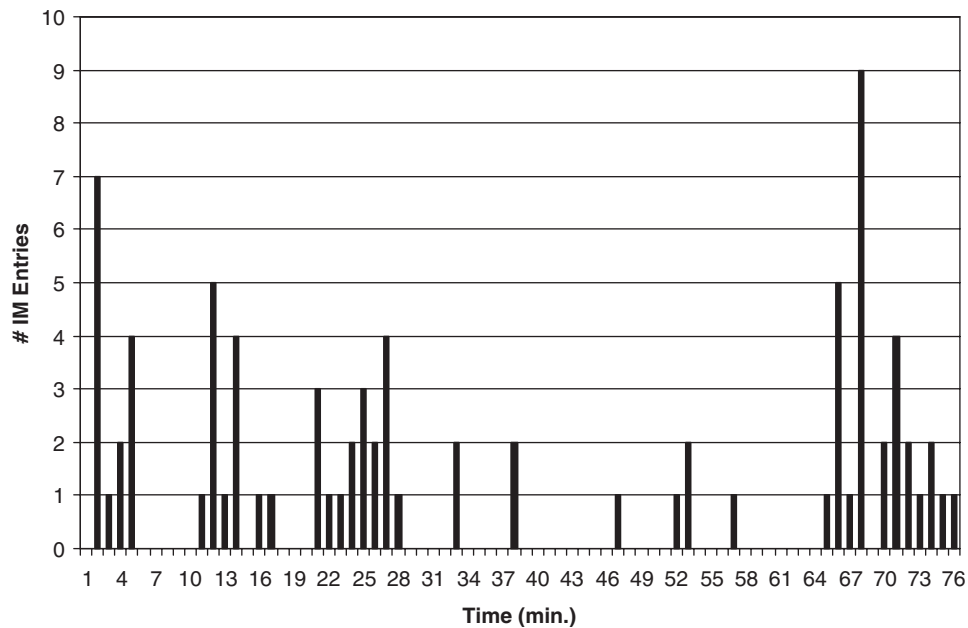


Fig 1 Instant messaging entries distributed over time in one meeting.

Table 1. Extract 1 from the 12th online meeting.

Line	Time	Contributor	Video stream	IM
1	21:11:05	Teacher		Which methods should Counter know of CounterView?
2	21:11:27	Teacher	Well, nothing . . . hmmm, I'm sorry, but I think it should, so . . .	
3	21:11:34	Barbara		Update?
4	21:11:36	Teacher		I think it should know something
5	21:11:44	Jack		setChanged(); notifyObservers();
6	21:12:04	Teacher	OK, Barbara she suggests 'update'.	

IM, instant messaging.

presents disruptions in the IRF structure – for example, when Barbara's suggestion is apparently 'ignored' for 30 s. In co-located settings, follow-up comments usually come immediately after responses. Several students reported the time delay as problematic when we discussed the online meetings with them in the interviews. One of them put it this way: 'I did not ask questions [. . .] I really had problems with the time delay [. . .] I felt that the question [the text] was communicated to the others after it was relevant'. Other issues that were brought up by students were problems because of typing speed or reluctance to 'speak in public'.

Understood in terms of an activity system, the issues we have discussed here represent a primary area

of tension in the mediating instruments. That is, the tension is positioned within the instrument component of the system. The instruments mediating the student's actions towards the learning community were MS media player (for the video stream) and *Yahoo! Messenger* (for the IM communication). The tension is found in the combination of the instruments; it appears in the time delay between the IM conference and the video stream. This tension seems to contribute to the low interactions.

The student's activities towards the other participants were mediated not only by instruments, but also by the rules of the activity. In our analysis, the rules include the norms and expectations present in the pedagogical approach the learning activity is based on

**Table 2.** Extract 2 from the 12th online meeting.

Time	Contributor	Video stream	IM
21:10:55	Teacher	If we should find the necessary knowledge from up here [indicates class 'Observable' in UML-diagram with the mouse] needed by this 'CounterView' we have down here [pointing with the mouse]. Which methods should 'Counter' call in 'CounterView'?	
	Teacher		Which methods should Counter know of CounterView?

IM, instant messaging.

– apprenticeship. Even though the intention in the course design was to use the meetings for discussions, all students might not share this ambition. When discussing the form of the meetings with a student, he said: 'I am comfortable with lectures. Many prefer dialogue, [and] that one do exercises and such, and that is fine too, but I am comfortable with just getting a lecture – I am happy with that. And that is the online meeting; it is perfect for just that'. This student referred to the online meetings as 'lectures' repeatedly throughout the interview. It is possible that there was a tension between the IOOP collaborative approach and the learners' expectations. To the extent this tension is rooted in the students' history and experience with learning in educational settings, this constitutes another primary area of tension, and it is found in the apprenticeship-motivated pedagogical approach.

### Participation

The data presented so far have indicated that the online meetings did not play out as intended in the course design. This should not be taken to mean that the students regarded the meetings as of little value. Almost all the students we interviewed pointed to the meetings as one of the important elements in the course design for their learning. Said one: 'It is obvious that the meetings with [the teacher] and the weekend seminars have had primary significance for my OO understanding. I used the textbook only for the Java-specific things'. Another issue indicating the usefulness of the meetings is the attendance rate. On average, approximately 70% of the students took part in the meetings. Participation in the meetings was not

a formal requirement. Many students shared the teachers' view that there was little activity in the IM conference. When asked if he had used the IM conference for raising questions during the meetings, one student replied: 'Yes, I have asked four questions. And I don't think there's too many who have done that. People have been a little slow in that respect'. Another student stated that 'we could have done without Yahoo! Messenger [...] it is too slow, sitting there pressing keys'.

The online meetings were captured while they were in progress. The recordings of the video streams were indexed and made available to the students for download within hours of the end of the meeting. The IM log was not distributed with the recordings; however, the teacher often included the text-based dialogue in the video stream, explicitly for the purpose of making the recordings more understandable. An example of this can be seen in the extract presented in Table 2, which took place immediately before the episode presented in Table 1. The question, slightly rephrased, is posed in both the IM dialogue and the video stream.

Given the moderate activity on the IM sessions, why did most students prefer to engage in the 'live event' at 8:30 PM on Thursday nights, instead of viewing the recording at their own convenience? Could this mean that participation in the meetings, as such, was important for the students? One passage from an interview with a student might indicate this. This student participated in all meetings but one, and he stated that he regarded his outcome of the meetings as fair. Later on in the interview, however, when questioned about if he asked questions during the

**Table 3.** IM entries categorized according to topic.

	Social	Technical	Moderation	Object orientation	Administrative	Error	Sum
Student	61	63	82	116	100	6	428
Teacher	19	27	107	50	88	1	292
Teaching assistant	8	9	14	7	10	0	48
Sum	88	99	203	173	198	7	728

IM, instant messaging.

meetings, he said: 'No, I might have asked a few simple questions, but not a lot. Because, many times, I have prepared for the meetings, and then you more or less know it yourself, the things that are offered'. His accounts can be taken to mean that even though he regarded it worthwhile to participate in the meetings, they did not contribute much to his understanding of the subject matter.

A more thorough examination of the IM dialogues might illuminate the students' motivation for participation. We have therefore studied what topics were discussed in the IM sessions. We have categorized all IM entries from the logs. The categorization is both data driven and informed by theory from computer-mediated communication (Feenberg 1989; Fjuk 1998). We found that many participants submitted a greeting when they joined the conference, at the outset of the sessions; similarly, many submitted a greeting before they logged off the sessions. We have labelled these entries as *social*. Another pattern that emerged was that the teacher often started off the meeting by asking the students about the quality of the audio and video transmission. We have labelled these questions, along with the responses from the students, as *technical*. During the sessions, the teacher submitted entries stating the next topic to be discussed, and asked the students if they found a preceding explanation sufficient; the teacher also asked if anyone had any questions. These entries, along with the students' replies and other comments on the progression of the meetings, have been categorized as *moderation*. Questions, replies, and comments on the subject matter itself have been labelled as *object orientation*. Entries regarding issues, such as how to submit assignments, where to find learning resources, how to sign up for new courses, or practicalities regarding the next weekend's seminar have been categorized as *administrative*. Finally, some entries that seemed to result from typing errors – such as entries without text or two identical

entries submitted almost simultaneously – have been categorized as *error*. A further distinction has been made according to who submitted the entry: the teacher, the teaching assistant, or a student. Entries generated by the IM application itself are not included in this overview. The number of entries in each category is presented in Table 3.

There were approximately the same number of entries in the categories *moderation*, *object-orientation* and *administrative*, and half as many in the categories *social* and *technical*. We regard the technical entries primarily as a means for conducting the meeting, to clarify if the students had any problems receiving the video stream. As such, these entries can be assumed to be of marginal interest to those students who only viewed the recordings. We interpret the moderation entries in a similar manner, that they are mechanisms for moving the meeting along. The number of entries in the category *administrative* indicates that the students used the opportunity presented by the meeting to clarify more pragmatic issues concerning the course. This aspect was not included in the intended role of the meetings; such issues were expected to be treated in an asynchronous discussion forum.

A large number of the entries categorized as *object-orientation* were specific questions from the teacher and the students' related replies. Thirty of the 116 entries from students in this category were phrased as a question.

Most of the entries in the *social* category were greetings from a participant joining or leaving the conference. These were not strictly necessary in informing other participants of one's actions (e.g. having joined the session), as this information was provided by the IM application. It is therefore interesting to note that many participants chose to make their presence explicitly known, or maybe acknowledge others' presence. The social aspect of participation will be taken up in the following section.

## Discussion

The course design aimed to create learning opportunities by providing resources in the learners' environment, as well as occasions for dialogical interactions. The interplay between these is a core issue in apprenticeship. However, the data presented in the previous section show that the participants regarded IM activity during the online meetings as being low. Further, we have indicated that about half of the IM entries can be expected to have only limited relevance for viewers of the recorded meetings. In addition, we have shown that the teacher, to some extent, included parts of the written dialogue in the video broadcast. An argument can therefore be made for considering individual viewing of the recordings as being roughly equal to participation in the online meetings, with respect to learning outcomes on object orientation. That is to say, the aspect of apprenticeship where the teacher demonstrates the skills and the systematic approach to the programming process of an experienced programmer are both maintained by the recordings.

Student flexibility with regard to time and place for studies is a central issue in theories on distance education (Paulsen 1993). Our interviews with the students indicate that this was also an important issue for them. Several stated that the distributed organization of the course made it possible for them to take part at all: most of the students held full-time jobs, and several of those we interviewed lived with their families between 1 and 4 h away from the university campus. The organization of the meetings represented a large degree of flexibility with regard to place, but they were not flexible with regard to time. The recordings provided flexibility in this respect too, as they could be viewed individually at any time after the meeting.

If the recordings are of equal value to participation in the meeting, and the recordings provide greater flexibility for the students, one possibility is to convert the online meetings into pre-produced videos. This would be an extension of what the teacher did prior to the start of the fall 2003 semester of the course, as described at the start of the previous section. He 'took out' the parts of the meeting that were 'one-way anyway', recorded videos in a manner similar to the meeting recordings, and made these available to the students on the course website. Such a conversion

would represent a transition from the dynamic, shared events constituted by the meetings, to reusable learning resources. One advantage of such an approach would be cost savings for the educational institution. A meeting could be recorded once, and supplied with metadata according to, for example, the SCORM specification (e.g. Chang *et al.* 2004). This learning object could then be reused in subsequent semesters at a low cost. Another benefit would be increased flexibility for the teacher, as he could produce the 'meetings' at a time most convenient for him.

This operational view of the online meetings, which underlies the line of reasoning in the previous paragraph, is contrasted by the findings in our analysis. The analysis has suggested that the meetings had meaning for the students beyond their outcome concerning object orientation. Analysis of the meetings at the level of the students' goal-directed actions gives more insight into this. The categories we found in the IM interactions indicate that participation in the meetings was directed towards at least three objects for the students: that related to the subject matter, social issues, and administrative issues.

One of the aims of the meetings in the course design was to help students solve the weekly assignments (i.e. to develop a better understanding of the subject matter). The data presented in the previous section indicate that some of the students' actions during the meetings were indeed directed towards this objective. Other actions – including the IM entries categorized as *social* – can be understood as being directed at establishing and maintaining social relations with the other participants; meeting participation in itself could to some extent also be taken as being directed towards this object. That is to say, the action of participation might be regarded as a statement of commitment to the group of students. Finally, the practical execution of the course can be considered the object of the actions represented by the *administrative* IM entries.

The short-term, goal-directed actions discussed so far are difficult to understand without a frame of reference created by the corresponding motive-driven, longer term activity. A key issue in constructing an activity system as an analytical framework is to identify the object of the activity. The object of activity is one of the most basic concepts of activity theory, and it can be regarded as 'the sense-maker' (Kaptelinin 2005). Transforming the object into an

outcome motivates the existence of an activity (Kuutti 1996). In Leontiev's structure of activity (Leontiev 1978), activities are isolated through analysis according to the motives that elicit them.

In using these theoretical considerations in the analysis, the projected outcome of the activity we analyse here might be increasing job opportunities for the students. By including object-oriented programming in their repertoire, the students can qualify for new tasks in their current work, or meet the requirements of other positions. We propose that the shared object of the activity, which is transformed into an outcome, is *the creation and maintenance of a community of learners* on fundamental object-oriented concepts and techniques.

This proposal is also founded on a sociocultural perspective of learning and human development. In this perspective, learning is understood as a fundamentally social process (Vygotsky 1978). In this analytical framework, an online meeting becomes one of several instruments mediating the students' actions towards the object of the activity system. Other instruments include weekend seminars, textbooks, assignments, *ad hoc* IM dialogues, etc.

From this perspective, the students' actions during the meetings should be understood as being directed towards the community of practice. Communities of practice are bound together by a collectively developed understanding of what the community is about; they are built by the mutual engagement of the participants, and they have produced a shared repertoire of communal resources (Wenger 2000). This implies that interactions of a social or administrative nature are not only legitimate but they are central parts of constituting the community.

This finding indicates that a transformation of the online meetings into reusable learning objects might disrupt important aspects of the students' learning processes. While issues regarding the subject domain might be maintained, such a transformation affects the students' opportunities with respect to constructing and maintaining the community of practice. This insight is founded on an awareness of internal systemic connections in the activity system we studied. When considering redesign of an ICT-mediated learning environment with respect to reuse and standardization, sensitivity towards such connections may be of profound importance.

We have shown that the shared events had a meaning for the IOOP students, which was not anticipated in the course design. We propose that designers of CSCL systems for distributed learning situations consider providing opportunities for such shared events, even though they might not be crucial with respect to knowledge-domain interactions.

## Conclusion

This article has explored the various roles of online meetings in the IOOP course. The study informs our understanding of the conditions in a specific learning situation, and contributes to the accumulated knowledge of what constitutes conditions for a productive online learning environment.

The apparent area of tension that has guided our analysis is that, despite the modest interactions during the online meetings and the opportunity to use recordings of them as an alternative, most students preferred to participate. Moreover, many students stated that they regarded the online meetings as an important resource in the course. We have identified primary areas of tension in the ICTs used and the pedagogical approach, which could facilitate more active student participation if resolved. More importantly, we suggest that the online meetings should be understood as a mediating instrument toward their community of practice. IM entries concerning the subject domain, social issues, and administrative issues are considered as contributions towards constructing and maintaining this community of practice.

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# Appendix E

## Paper V

Berge, O. and Fjuk, A. (2006)

*Reuse of Learning Resources in Object-Oriented Learning*

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## Chapter 8

# Reuse of learning resources in object-oriented learning

*Ola Berge and Annita Fjuk*

**Abstract.** *Facilitation of the reuse of learning resources through standardization is regarded as vital for the sustainable deployment of digital learning resources. The aim of this research is to inform the increasing work on standardization through exploring what kinds of learning resource are reusable across learning situations. With this aim in mind, we conducted an embedded case study on two instances of an online course that constitutes an introduction to object-oriented programming. The result of the analysis is a tentative taxonomy of reuse. This taxonomy includes four levels of reuse: learning material (primary level), course design components (secondary level), course design (tertiary level), and pedagogical approach (quaternary level). We argue that current standards for, and specifications of, learning technology are primarily concerned with reuse at the primary and tertiary levels, and do not address explicitly the secondary and quaternary levels.*

### Introduction

The primary motivation of the study presented in this chapter was to investigate the use and reuse of learning resources. The rationale for this was the increased use of digital learning resources in educational institutions. This trend has led to a corresponding interest in improving the cost-efficiency related to developing and deploying such resources within these institutions (e.g. Littlejohn, 2003; McGreal, 2004). Facilitation of the reuse of learning resources through standardization is regarded as vital for sustainable deployment of digital learning resources. This study is not concerned with how to specify standards for learning resources. Rather, it explores what kinds of learning resources are suitable for reuse and how they can be reused. One important result of this research is a tentative taxonomy of reuse, which can be used as a guide

when making decisions about the deployment of learning technology standards.

A central concept in efforts to standardize learning content is *learning objects*. The fundamental idea behind learning objects is that developers of learning material can build small (relative to the size of an entire course) instructional components that can be reused a number of times in different learning situations. In addition, learning objects are generally understood to be digital units that can be delivered over the Internet. Learning content is broken down into modules, where the content of the module is described with metadata. A standardized approach to the design of learning objects has the potential of achieving several benefits: modules can be used in different courses, they can be used within different Learning Management Systems, and they can be updated more easily than a larger block of content. The content in the learning object can be any element usually associated with multimedia content: text, graphics, animation, sound, video, or a combination of these. Learning objects have been compared to objects as we know them from computer science (Wiley, 2000). The “Smalltalk-tradition” of object-orientation emphasizes modularization and reuse, an approach shared with the concept of learning objects. However, the similarity is only superficial. There are, for example, important object-oriented concepts, such as classes, inheritance, methods, and parameter passing, that are not included in the concept of learning objects.

The Sharable Content Object Reference Model (SCORM) is emerging as the predominant approach to standardization among early adopters of learning object technology (Edmonds and Barron, 2002), and is therefore afforded special attention in this chapter. These early adopters are primarily concerned with corporate training, or training in the US military. SCORM is developed by the Advanced Distributed Learning Initiative (ADL), launched in 1997 by the US Department of Defense and the White House Office of Science and Technology Policy. The primary motivation for the development of the SCORM (ADL 2004) was to enhance learning while improving efficiency and reducing costs related to the production of digital learning content. SCORM aims to foster the creation of reusable learning content as instructional objects within a common technical framework for computer and Web-based learning. While SCORM might aim at being agnostic with respect to pedagogical approaches, there is some concern that SCORM-based content would not respond equally well to pedagogical approaches

found within formal educational contexts (e.g. Friesen, 2004; Hoel, 2003; Koper and Oliver, 2004; Welsch, 2002).

The Learning Design specification (IMS 2003a) from IMS Global Learning Consortium, one of the contributors to SCORM, takes a different approach to promoting exchange and interoperability of digital learning materials. While SCORM is focused on tailoring content to individuals and tracking the individual's interactions with the content, a key task of the working group behind IMS LD was "the development of a framework that supports pedagogical diversity and innovation" (IMS, 2003a, p. 4). IMS LD facilitates reuse of teaching strategies (pedagogical approaches) and educational goals. Each element of content is associated with information that describes its instructional strategy, and this information can be used for adapting the content to a pedagogical approach that is different from the one for which it was designed. "By labeling the strategy and the components of the strategy in a common, machine-readable manner, the context of a learning opportunity can be managed separately from the content itself" (IMS, 2003b, p. 4). An example of a more detailed discussion of SCORM and IMS Learning Design, in the context of inquiry-based learning, may be found in Berge and Slotta (2006).

It is arguable that for the design and deployment of learning technology standards, a thorough understanding of the use and reuse of learning resources in a wide variety of learning situations would be beneficial. Given the situated nature of learning, we contend that such an understanding should be founded on studies of specific learning situations. The study reported in this chapter contributes to the accumulation of knowledge within this field. The study was aimed at exploring use and reuse of learning resources across two instances of an online course that constituted an introduction to object-oriented programming (IOOP), delivered at Aarhus University in Denmark. One of the most interesting aspects of this particular course is the *process-oriented view* of learning how to program. That is, the learning objective is the analytical and creative process of programming, rather than programming language constructs and solving small example problems. Most available learning resources (such as text books) within this field, tend to be structured according to the latter learning objective (Kölling and Barnes, 2004), which means that the IOOP course design requires the design of new learning resources or reuse of resources directed towards other learning objectives or learning situations. Another interesting

aspect of this particular course is its online delivery and, as such, it contains a rich combination of digital and non-digital learning resources and Information- and Communication Technologies (ICTs). Hence, the IOOP online course design demonstrates a situated complexity that is anchored in a basic philosophical view on object-orientation as well as how this should be taught for learners through a variety of learning resources.

In the coming sections, we report on how the course design worked in practice in two instances of the IOOP course. Our particular focus in this study is the use and reuse of the learning resources, within and across the two instances. The structure of the rest of this chapter is as follows. First, we present the course design of IOOP. Then, we give an account of our methodological standpoint and how we carried out the embedded case study on the two instances of IOOP. Next, we present our findings on reuse of learning resources in the two semesters of IOOP. The chapter concludes with a discussion of the central findings, systemized in a taxonomy of reuse, and how they relate to ongoing initiatives regarding standardization.

## **IOOP course design**

This section describes the IOOP course, along with the initial intention behind its design. With basis in a sociocultural tradition (Chapter 2), this does not necessarily represent how the artifacts (e.g., learning resources and ICTs) were actually used. The artifacts may not evolve for the purposes they were designed (Wertsch, 1998). Furthermore, learners may act and learn, to some extent, in a manner not intended by the teacher or course designer. “The ongoing tension and excitement lies exactly in the fact that instruction is not merely transmission, pouring knowledge into empty boxes” (Engeström, 1994, p. 47). An account of how some aspects of the course worked in practice during the two observed instances is reported in sections IOOP 03 and IOOP 04.

### ***The learning environment***

The IOOP course has been taught as an on-campus course at Aarhus University in Denmark for about ten years. The principal learning objective is the *processes of programming*, rather than a correctly executable program code in Java. Programming is viewed as a creative and analytical activity, where the programmer starts with a vague idea of a solution

and then articulates and models the thoughts into an executable program. A pedagogical approach that enhances such a creative activity itself, in rich combination with showing the learners how an expert programmer works in these processes, has gradually been considered vital for the IOOP course design. However, modern pedagogical perspectives that emphasize an understanding of language, culture and the cognitive development that occurs through interactions between learners as well as between learners and teachers (Scott et al., 1992) have not been consciously included in the on-campus course. The online course design was aimed explicitly at including aspects of the sociocultural perspective on human development, according to which learners actively generate, access and organize information, constructing and refining their own knowledge through feedback from peers and the teacher. Elsewhere (Bennedsen et al., 2005; Chapter 9) we propose that these facets of the online course design mirror those often found in apprenticeship learning (Nielsen and Kvale, 1997; Lave and Wenger, 1991).

A vital aspect of the IOOP online course design was then to find instruments that support the following:

- Information sharing and joint creation of meaning amongst the learners.
- Teacher's reflection in action in terms of both natural and scientific language, as well as for showing the creative process of programming.
- Teacher's information on the learners' knowledge and progression.

The learners were adult part-time learners committed to a daily work community with few opportunities to take part in the learning environment during regular working hours. ICT-based applications that were easily accessible from the learners' PCs and network connections at home were important conditions for the course design. In the following, we will focus on the instruments that were most central in the course design.

## **Week memo**

The course was organized in units of one week each. With few exceptions, a week memo was posted on the IOOP web site, containing an overview of the topics to be covered that week, readings for the week

(reference to textbook and additional material), comments on the readings (“reading guide”), agenda for the online meeting, the weekly assignment, and links to various pre-produced learning materials. The agenda for the online meetings typically contained a brief description of the topics to be covered, suggestions for preparation for the meeting, and sometimes source code for examples covered in the meeting.

## **Online meetings**

The *online meetings*, arranged once a week, constituted the core of the online course design. The topics treated in these meetings were based on the individual learners’ experiences in completing the weekly assignment, combined with her / his request. The meetings were mediated by real-time video streaming of the teacher’s PC screen, where his use of the various programming and modeling tools (such as e.g. the Java Development Environment BlueJ) were shown. There was a corresponding audio stream, by which the learners could hear how the teacher reasoned and thought aloud about the problem. In order to mediate interactions amongst learners and between learner and teacher during the online meetings, a *text-based Instant Messaging (IM) conference* was arranged (using Yahoo! Messenger) in conjunction with the real-time video stream.

The video stream from the meetings was captured during the meetings and stored on the course web site so that the learners could review them later in their study. The videos were indexed by short descriptions of the central activities in the meeting with corresponding time stamps.

## **Assignments**

The assignments constituted the primary resources for acquiring knowledge of the syntax and semantics of Java, as well as for providing practical and hands-on skills on, e.g., the execution of program code. The assignments were also intended as a means for the teacher to gain insight into the students’ understanding of the knowledge domain. The students were given one assignment each week. A prerequisite for entering the exam was that the student passed at least 80% of the assignments.



## **Pre-produced digital videos**

Along with the assignments, pre-produced digital video material was developed, to give the learners hints associated with the assignments or to offer explanations alternative to those found in the textbook. These videos are audio-visual recordings of the teacher's actions, and his comments on his actions, while working in the BlueJ development environment. The videos were prepared by the teacher using modest technical means, and are typically 2 - 15 minutes long, with some lasting almost an hour. Some videos supplement the textbook by offering alternative explanations of concepts using examples, others show how the teacher approaches the weekly assignments, others show how he solves them, and yet others offer guidance in the practical use of tools.

## **Course readings and programming tools**

The book *Objects First with Java - A Practical Introduction using BlueJ* (Barnes and Kölling, 2003) was the primary text-book. The BlueJ Java Development Environment (Kölling et al., 2003; Chapter 6) is integrated with this book and, as such, constituted an important programming tool in the course. In addition, the IOOP web site provides links to resources such as the Java language specification and Java Standard Development Kit Documentation.

## **Weekend seminars**

Three two-day weekend seminars were arranged on campus during the semester. The primary activities during these seminars were lectures and group work on practical tasks. The lectures primarily addressed conceptual issues on object-orientation, topics where the teacher regarded the format of co-located lectures as more suitable than net-based meetings. One vital objective of the seminars was to stimulate collaborative activities among the students during the periods they worked distributed.

## **Other resources**

All the video-based material was stored in a searchable resource repository (Bennedsen, 2004). A collection of exercises pertaining to the subject matter was also available to the learners. This is a collection built over time by the designers of IOOP, aimed at introductory programming courses (CS1) in general. This collection also includes source code

for the exercises. A web-based, asynchronous discussion forum (Bazaar) was provided to enable learners to communicate with peers and faculty when time was not a critical factor.

## **Method**

To understand use and reuse of learning resources, we find it important to gain insights into the rationale behind the course design, how teachers implement the design principles into their teaching, and how learners use the learning resources in their learning processes. Furthermore, in order to inform the design and application of standards for reusable learning material, it was necessary to obtain an understanding of (i) *why* these practices occur; and (ii) how the design rationale was implemented across semesters of the course. Against this background, the study was designed as an embedded case study (Yin, 2003), comprised of the two case studies IOOP 03 (fall 2003) and IOOP 04 (spring 2004). Our research interests are anchored in an understanding of practice from the point of view of the participants, through the learners' and the teachers' own talk and experiences. By analyzing how learning resources are used in the two semesters, and by comparing their roles in the two semesters, we expected our research design to yield insights into this aspect of reuse. The following two sections describe how data was collected in the two case studies.

### ***The IOOP 03 case study***

The IOOP 03 course was organized as a part of a Masters program in software construction. Some of the learners participated in the course as a part of their Master's degree, others attended only this course. Most of the learners had prior knowledge in programming (not necessarily object-orientation) and stated clearly that their motive for participating in the course was related to daily or future work practice. The teacher was one of the two persons who designed the course, which was first offered during the spring of 03. The autumn 03 course started with a weekend seminar and ended with the final examination. Fourteen week memos were published.

The data was gathered by observation of online activities, including 10 of the 14 weekly online meetings, and postings on the discussion board. Documents and learning resources available on the course web site were also gathered for analysis. In addition, data was collected (i) by

observing one weekend seminar out of the three given, which included video recordings of some events, and (ii) by means of a survey carried out among the learners as part of the regular course evaluation. Finally, in-depth interviews with nine learners, the teacher, and the teaching assistant were carried out just after the final examination. In addition, one interview with the teacher took place early in the semester, focusing on the course design and its rationale. The interviews constituted the primary source of data for the research presented in this chapter, together with the analysis of the learning resources. The other data was used as background for the interviews.

In this instance of the course 22 learners attended. There was one teacher and one teaching assistant (who helped with, for example, technical problems during the online meetings). Both authors carried out the case study.

### ***The IOOP 04 case study***

The IOOP 04 course was organized as a part of a Masters program in multimedia design. As with the previous semester, some of the learners participated in the course as a part of their Master's degree, while others attended only this course. The primary motivation for many of the learners was to gain insights into how a programmer works and not necessarily to become a programmer themselves. While the teaching assistant was the same as in the previous semester, the teacher was new to the course.

As the IOOP 03 case, the course started with a weekend seminar and ended with a final examination. Fourteen week memos were published. Four face-to-face weekend seminars were held during the semester, the last one a one-day seminar for a question and answer session and summarization of the subject matter. This seminar was arranged three weeks before the final examination. Twelve learners attended this semester of the course.

In a manner similar to that in the preceding case study, data was collected by observation of online activities, primarily the online meetings (10 of 14) and postings to the discussion forum. Additionally, one weekend seminar was observed by passive participation. In-depth interviews were carried out with four learners, the teaching assistant, and the teacher. The data gathered also included documents and learning resources available on the IOOP web site. As with the IOOP 03 study,

our findings in this chapter are primarily based on data from the interviews. The first author carried out this case study.

## **Use and reuse of learning resources**

This section presents our findings with regard to the use and reuse of learning resources in the IOOP course. First, we show which kinds of reuse we identified in the IOOP 03 study, and categorize these with respect to the context in which they were developed. Thereafter, we present our findings from the 04 semester, including the reuse of resources from the 03 study.

The learners' and teachers' quotes included in the following, are translated literally from Norwegian.

### ***IOOP 03***

The use of textbooks represents an established form for reuse of learning materials, and probably the most widespread one. We found this kind of reuse in IOOP 03, represented by the textbook 'Objects First with Java - A Practical Introduction using BlueJ'. This is a resource developed for intentional learning situations by a third party, i.e. outside the scope of IOOP. Other learning resources not specifically designed for the IOOP course includes chapters from books and articles covering specific topics of object-orientation (such as a conceptual framework of OO or graphical interfaces in Java) and presentations made in the context of other introductory courses on computer science.

In addition to this reading material, the exercises used were taken from a collection developed over time by the designers of IOOP for introductory computer science in general. These were also developed for intentional learning situations, but they represent a different kind of reuse, as they were developed by the teacher of the course, not by someone outside IOOP. Some presentations used during the course also constituted this kind of reuse.

External resources, such as the Java language specification and Java Standard Development Kit documentation, were made available to the learners. These materials were not designed for intentional learning situations, but rather as reference works for Java programmers. The inclusion of these materials thus denotes a particular mode of reuse,

which we might call *repurposing*, i.e. they were used for purposes different from those they were designed for.

So far, we have presented reuse of pre-produced learning resources. The recordings of the online meetings represent a different kind of learning resource, in that they were created dynamically during the progress of the course. We found that the recordings were, to a great extent, used as intended in the course design, primarily as a part of the learners' preparation for the final examination. They were also used by learners who did not attend particular meetings and by some for revisiting specific, challenging issues. This use represents an interesting form of reuse, where part of the practice of the community of learners is captured – or reified (Wenger, 1998) – and made available for the community with little overhead in terms of the extra effort required for capture and publication.

#### **Four identified categories of reuse**

The first category of reuse we described in this section comprises the use of learning resources created and maintained outside the specific learning situation in which it is used. The second category also comprises the use of material developed for intentional learning situations, but produced by the teacher of the course. The third category comprises the repurposing of material developed for situations other than intentional learning situations, by a third party. Finally, the fourth category comprises the use of material created by the community during the course of their collective activity of learning object-orientation.

#### ***IOOP 04***

As noted above, in the spring semester 2004, a new teacher replaced the previous one. The new teacher had very little time to prepare for the course. According to the teacher, this shortage of time had a strong impact on how he reused learning material from IOOP 03.

I was thrown into it,

he states in the interview.

And, uncharacteristically, I was quite unprepared. I was therefore forced to use a lot of material that was there from earlier on, and that was a new experience for me. Because I have perceived it as of higher quality to make it one self. Of course one

makes one's own slide, of course one makes one's own everything. It was a very exiting experience, because I came to appreciate that it could be meaningful, even though I encountered material where I was thinking that I could have done this a little different, if I had the time.

Overall, the IOOP course design was reused with regard to the week being the central organizational unit (such as weekly assignments and online meetings). The IOOP 04 teacher shared with his predecessor both the fundamental perspective on object-orientation and the course philosophy. Therefore, the overall progression of the course, the variety of ICTs used and the more specialized tools such as the BlueJ Java development environment, remained basically unchanged.

On a more detailed level, the IOOP 04 teacher used the same textbook, the same additional course readings and the same links to the external online Java resources. He also used the same exercises and assignments as the IOOP 03 teacher. However, he did not reuse the examples used in the online meetings, but used examples he developed himself, about half of which he designed specifically for the IOOP course. For the other examples he reused his own, earlier, material. He did not, however, use much of the video-based material developed by his predecessor.

My point of departure was that I could not use the videos, it was simply too weak not to make those myself. But I was in a position where I could not make them myself, due to time pressure, and after a while I came to realize that I could use some of them.

About halfway into the course, he started to add links to the 'How to approach the assignment'-videos from the weekly memo. Furthermore, the IOOP 04 teacher did view the recordings of the IOOP 03 online meetings.

I used them for inspiration, not as a template,

he explained in the interview. He did not make these recordings, or the other video-material, explicitly available to his learners (with the exception noted above). However, the IOOP 04 web site did have a link to the previous semester's web site, where all the digital material could be found. One challenge the IOOP 04 teacher met was to locate much of the material he reused from IOOP 03.

I had to sift through literally hundreds of files to find what I wanted,

he stated in the interview. All the material was stored on a university server, but it was poorly structured and located together with a large amount of unused material, according to the IOOP 04 teacher.

So far, we have discussed the reuse of resources that falls into the three first categories identified in the previous section: resources developed for intentional learning situations by a third party, resources developed by the teacher of the course, and repurposing of external resources. In addition, we found reuse of learning material developed specifically for the course, but not by the current teacher. This can be regarded as a special case of the first category, resources developed for intentional learning situations by a third party. Looking beyond the context of the learning resources, we also found that the IOOP 04 teacher leveraged other aspects of IOOP 03. This pertains to the overall pedagogical approach, including the idea of online meetings, the constellation of ICT-based mediational tools, the curriculum, the progression of the course, the weekly memos, and assignments. Traditionally, the use of tools such the IM conference might not be regarded as reuse, but the particular constellation of tools used in IOOP is a carefully designed whole that represents, in conceptual terms, a resource that was reused by the IOOP 04 teacher. Thus, in addition to various forms of reuse of learning resources, our study revealed a more basic level of reuse between the two semesters.

The IOOP 04 teacher also made some modifications to how some of the ICT-based tools were used. One interesting example is how he used an asynchronous discussion forum for distributing the completed assignments from the individual learners with his comments on their solutions. This tool was chosen because access to it was limited to the IOOP participants, unlike, e.g., the course web site.

The roles of the online meetings in the IOOP 03 course are analyzed by Berge and Fjuk (2006). This study shows that despite modest student activity in the meetings, and the opportunity to use the recordings as an alternative, most students preferred to participate in the shared event. The study suggests that the online meetings should be regarded as instruments that mediate the participants' construction and maintenance of a community dedicated to learning object-orientation. That is, the meetings had meaning for the students beyond the subject matter

treated in them. Our study of the IOOP 04 online meetings strengthens and supplements the findings from the IOOP 03 meetings. Like the meetings in the previous semester, the 04 meetings were characterized by high learner attendance but little social interaction on the subject matter. Several learners expressed that the lack of interaction during the meetings represented a challenge with regard to concentrating on what was being said. One learner said:

The [IM] chat dialog did not contain much. I wish for a more ... offensive, or pushing, approach from the teacher, in the form of asking questions that are expected to be answered.

However, the opportunity represented by the IM conference seems to have had some significance. Another learner, asked about whether he would prefer to just view the recordings instead of participating in the meetings, replied:

I think it is better to be there online, not just play a video stream. Because there is something psychological in that it happens concurrently, and that one participates in the chat. Even though there weren't much communication on the chat, having the possibility means that you are different mentally from if you just sit back and listen.

As in IOOP 03, this indicates that the online meetings might provide more than just explanations of topics from the subject matter: They had a role in addition to the strictly professional aspects. One learner was particularly clear on this point:

[The online meetings] have been very important because they have been our coordination point, for all the participants. And they have been important for the course.

The recordings were also used in a manner similar to that in which they were used in IOOP 03; as preparation for the examination and as catch-up material by learners that did not attend the meetings. Yet in addition, some learners in IOOP 04 reused recordings from IOOP 03. One learner, who also participated in most of the online meetings, said:

I rather used the recordings from the fall semester of the same course. I did that because the way [the IOOP 03 teacher] explained things was much more understandable for me. He has a more pragmatic approach and his totally practical and concrete down on a level where one can understand it. I think that



[the IOOP 04 teacher], who is also skilful, explains it on a more abstract level. Therefore, I have actually viewed two sets of videos, I have seen a pragmatic and an abstract approach, and then understood it in my way.

Another learner stated that he had downloaded the videos from all the IOOP 03 meetings. He could use the index to find where in the video the topics he was interested in were located; he did not have to watch it in its entirety.

Our analysis of IOOP 03 and IOOP 04 reveals that the online meetings had multiple roles. This finding indicates important issues that are of concern regarding standardization of learning resources. Implications of this for reflections on deployment of standards coming out of this are discussed in the following section.

## Reuse and standardization

The findings from the studies presented in the previous section suggest different categories and levels of reuse. These are systematized into a tentative taxonomy, presented in Table 1, and are discussed below.

Table 1. A tentative taxonomy of reuse.

Quaternary	Pedagogical approach			
Tertiary	Course design			
Secondary	Course design components			
Primary	Own material	External material	Repurposed external material	Reification of practice

### Primary level reuse

We have shown that there was extensive reuse of preproduced learning resources across the two semesters. We have distinguished between four categories of such resources at this level, which we call the *primary level*. The reuse of learning resources designed for intentional learning contexts fall into two categories: reuse of the teacher's own material (e.g. exercises) and reuse of material developed by a third party (e.g. textbook). Concerning the latter category, we have the special case of learning material developed for the particular course, but not by the

current teacher (e.g. pre-produced video). The third category is reuse of resources not designed specifically for intentional learning contexts, which we called repurposing (e.g. Java documentation). These three categories represent reuse in the sense that it is use of resources developed and maintained outside the scope of the course it is used in. The fourth category comprises resources that are reifications of the practice of the community constituted by the participants in the course. The prime example of this is the recordings from the online meetings, but the completed and commented assignments are also an instance of this kind of reuse. We have found that these are reused within the course, but also, to some extent, across semesters.

Both the exercises and the weekly assignments from IOOP 03 were reused in IOOP 04, but the examples used in the meetings were not. In the interviews, the teachers stated that they regarded it as important that the exercises be designed carefully and described precisely, and that they are often subject to refinement over time. Examples, however, can be described more loosely, because the teacher can interpret them and make assumptions during their explanation and implementation. The examples also seem to be subject to the teachers' personal style and preferences more than other learning material. The pre-produced videos represent another kind of learning resource that was reused sparsely. Although the IOOP 04 teacher used some of them, he was reluctant to do so at the outset. He believed that he should make similar videos himself, but realized after a while that he did not have the time. Again, this seems to be a matter of personal style. In the interview he stated that he would prefer to explain the various phenomena in his own way.

### **Secondary level reuse**

As our presentation of the two instances of IOOP has shown, the IOOP 04 teacher reused components of the course design extensively. One such component is the online meeting, composed of a constellation of ICTs (the video-streaming software and the settings used for the particular set-up, the IM application, the client media player), the ICT-based tools (BlueJ, PowerPoint, etc.), and pedagogical principles concerning social interactions. Other examples of course design component reuse are the weekend seminars and the asynchronous discussion forum. We designate this *secondary level* reuse.

We found the online meetings especially interesting with respect to reuse at this level. The study of the IOOP 03 meetings indicates that the students regarded them as an important resource for understanding basic object-oriented concepts (Berge and Fjuk, 2006). Our interviews with the IOOP 04 students support this finding. Due to the modest student IM activity during the meetings, an argument can be made for regarding individual viewing of the recordings of the meetings as being almost equal to participation in the meetings, with respect to the learning outcome on object-orientation. Following from this, it may be tempting to capture only the actions of the teacher and make the resultant video available to the learners for online viewing or download, transforming the online meetings from synchronous events to asynchronous learning resources. This would constitute a transformation from secondary level reuse (the online meetings) to primary level reuse (of the recordings). That is, to use the same approach as with the other pre-produced, video-based material available to the learners. A potential benefit of this would be reduction of costs for the educational institution as well as for the teacher, since the online meetings could be dispensed with and one could rely only on the recordings. But, as shown by Berge and Fjuk (2006), and in our analysis of IOOP 04, the role of the online meetings is very different from those of the pre-produced video material. The meetings should be understood as an instrument for constructing and maintaining a community of practice. Communities of practice are bound together by a collective developed understanding of what the community is about, they are built by the mutual engagement of the participants, and they produce a shared repertoire of communal resources (Wenger, 2000). One implication of this is that participation in the shared event *per se* is important.

A transformation as suggested would probably imply an inconsistency regarding the objective of the learning activity and the ideal that this is situated in a social practice of co-learners and a constellation of tools. In turn, this would have consequences for the pedagogical approach in which social interactions amongst learners and between learners and teacher is a fundamental principle. Based on our study, we claim that the reuse of dynamic learning resources (such as the meetings) should be sensitive to pedagogical and organizational factors, since they rest fundamentally on those factors.

### **Tertiary level reuse**

Our case study showed that not only components, but also the whole *course design*, were reused in IOOP 04. By course design, we here refer to the overall organization of the course: the distinct units framed by the week, the curriculum and the progression of the course, the weekend seminars, the distributed organization, etc. We regard this level of reuse – the *tertiary level* – as distinct from the secondary level. This kind of reuse is also widespread in educational practice. In campus-based education, for example, many introductory programming courses follow a similar pattern of two lectures and one computer laboratory session a week, together with the learners' individual studies. The various courses may vary in the specific curriculum and in what sequence programming concepts are introduced, as well as what tools are chosen for the courses. However, the tradition of organizing introductory programming as online learning is short, and thus there is no established body of experiences to draw from. The course design is, as we have seen, a complex mix of interwoven aspects, and capturing productive constellations can help this field of practice to develop.

### **Quaternary level of reuse**

At the *quaternary level* of reuse we find the driving pedagogical approach. Reuse of pedagogical approaches is obviously nothing new. The accumulated experience from educators and researchers in this field is extensively documented; there are hundreds of different pedagogical models described in the literature and new models continue to be formulated (Koper and Oliver, 2004). The IOOP course design was developed and organized by the IOOP 03 teacher, and he gradually developed the rationale behind the design through many years of teaching object-oriented programming. One result of this practice was a pedagogical approach that incorporates some facets that traditionally are found outside educational contexts, but are inspired by a master-apprentice relationship. This particular approach had an essential role to play in how the different learning resources were organized and, not least, in how the teacher should act.

Our studies indicate that the IOOP 04 teacher reused this particular approach to a large extent. However, he practiced it through a more traditional lecturing role, rather than as a master who involves the learners in social interactions and legitimates their actions. This may

indicate the challenge of reusing the pedagogical approach as intended in the initial course design.

Another aspect connected to reuse of the pedagogical approach, may be manifested in the identity of the learners. Many IOOP 04 learners quite interestingly reported (in interviews) that they had initiated and taken part in collaboratively oriented activities, in both on-line and face-to-face contexts. In addition to this, some also reused the recorded meetings from IOOP 03. They used the IOOP 03 recordings to get alternative perspectives on the subject matter, which offered a richer approach to object-orientation for them. These issues might indicate that the IOOP 04 learners (of whom a few had practiced programming outside the course) to a greater extent than the IOOP 03 learners (many of whom had practiced programming in their work) had a stronger need to take part in communities of collaborating learners *and* to use a rich constellation of learning resources to create meaning and knowledge on object-orientation.

### ***Implications for standardization***

The *primary level* categorizes reusable learning material. Such resources constitute the focus of SCORM, where they are treated as learning objects. Learning objects are described by metadata, which enables discovery of the resources. SCORM uses an application profile of the IEEE LOM standard for specifying metadata. Tagging of the learning objects with metadata means extra work for the development of learning material, and it is therefore of interest to reflect on what kinds of resources that should be tagged with metadata. It is doubtful whether reuse of the teacher's own material will benefit substantially from being tagged according to IEEE LOM or similar metadata schemas, as it may be expected that the creators of such material will have their own mechanisms for finding it (e.g. folder hierarchies and file naming conventions). Discovery of external material, however, is probably much alleviated by this kind of metadata. An example of this is the frustrations of the IOOP 04 teacher when he was trying to locate material used in the previous semester. In a wider context, learning object repositories are often regarded as a suitable means of sharing content.

The question of granularity is of interest in the design of learning objects. The basic approach is to modularize the content to facilitate for reuse. We have used the textbook as an example of reuse of external

material. Textbooks are usually regarded as being of too coarse a grain size in the context of learning objects; the pre-produced videos are more typical candidates for learning objects. Concerning the repurposing of external material, one cannot expect the creators to furnish the material with IEEE LOM metadata, as they are not explicitly designed for intentional learning contexts. One possibility is for educators to create learning objects that describe and reference such resources, and store these objects in repositories. Finally, the reuse of materials that are reifications of practice might benefit from metadata. The IOOP 03 online meeting recordings were tagged with metadata (not IEEE LOM) and stored in a repository. The intention was to provide a mechanism for discovery by the learners in addition to chronological organization. This repository was not used to a large extent by the learners, but some of the metadata (time-stamped subject index) was actively used by some. Some learners also used the recordings in the following semester, but they primarily used the context of the weekly memos to locate the recordings. We believe that the use of these recordings was highly situated, and we cannot assume that they will have great value for learners outside IOOP. We have thus not found strong indications that suggest that metadata tagging of these according to IEEE LOM would be of great value.

The *secondary level* concerns the reuse of components of the learning design, the combination of purpose in the overall context, and the mechanisms for implementing this. This level of reuse is, to some extent, addressed by IMS Learning Design (LD). LD is modeling 'units of learning', which are the "smallest unit providing learning events for the learner, enabling one or more interrelated learning objectives. This means that a unit of learning cannot be broken down to its component parts without losing its semantic and pragmatic meaning and its effectiveness in guiding learners towards the attainment of learning objectives." (Koper and Es, 2004, p. 44). The components at the secondary level of reuse in our taxonomy do not constitute units of learning; they are rather elements in such units. However, they can be extracted from complete learning designs, and reused in other designs. We are not aware of any learning technology standards that address the secondary level of reuse explicitly.

The *tertiary level* is reuse of the course design. In the special case of an individual learner working exclusively with ICT-based learning material, standardization of course design is accommodated by SCORM; but for

the more general case, the approach taken by IMS LD is of more interest. This specification includes support for both single- and multiple-user models of learning, and support for mixed-mode as well as pure online learning. The approach taken in IMS LD is to associate educational content with information that describes its instructional strategy. In the context of the taxonomy suggested here, this means that it is possible to describe the course design (the tertiary level) and associate this description with lower-level resources. This association is not static; individual resources can be replaced. The IMS LD is relatively new and is not widely supported in educational technology. However, we regard this approach as promising for standardized descriptions for the support of tertiary level reuse. An alternative to IMS LD in the application area of Computer Supported Collaborative Learning (CSCL) might be CSCL scripts. This approach, proposed by Miao et al. (2005), entails the development of formalized collaborative learning scripts. A collaboration script is a set of instructions that specifies how the group members should interact and collaborate to solve a problem (O'Donnel and Dansereau, 1992). One application of CSCL scripts is to use them as a source for a configuration tool to support runtime environments during the learning process. This approach is conceptually similar to the one in IMS LD. A CSCL script is a specific learning design, which can reference learning resources and tools. The CSCL scripting language has the potential of supporting reuse at the tertiary level.

*Quaternary level* reuse is, to some extent, supported by the large body of literature in the field of pedagogy. Descriptions of various pedagogical approaches vary strongly in the level of detail; some are quite detailed prescriptions, while others cover more general concepts. The Pedagogical Patterns Project is one initiative that aims at capturing best practice within specific educational domains (e.g. Eckstein et al., 2003). The intent is to summarize expert knowledge of practice in a compact form and communicate this to those who need it. Pedagogical patterns often formulate didactical strategies, providing practical guidelines for teachers on issues such as motivating students or arranging seminars. Pedagogical patterns are not expressed in a strict, formal format that can be applied directly, and are usually not discussed in the context of standards for learning technology.

We conclude our discussion of use and reuse of learning resources with an issue identified through our analysis of the online meetings and of how the recordings of these meetings were used, because it offers in-

sights of interest for deliberations on deployment of standards for e-learning. The finding that the IOOP 04 learners used the recordings of the IOOP 03 meetings as a supplement to the IOOP 04 meetings might indicate an issue with implications for the motivation for standardizing learning material. Two key contributors to SCORM state that the driving force behind the large-scale sharing and reuse of multimedia content components “stems from the notion that repurposing of such components can lead to important savings in time and money, and can enhance the quality of digital learning experiences” (Duval and Hodgins, 2004, p. 72). ADL, the developers of SCORM, aims to “accelerate large-scale development of dynamic and cost-effective learning software and systems and to stimulate the market for these products” (ADL, 2004, pp. 1-3). The IOOP 04 students used the IOOP 03 recordings in addition to the IOOP 04 recordings, not instead of them. As such, this form of reuse did not represent cost savings for the institution. The learners’ reuse of recordings across semesters provided supplementary material for them, which addresses issues related to quality rather than financial benefit in a narrow sense. Our study therefore indicates that a discussion of the introduction of standardized learning material might profit from taking into account such issues as access to a more diverse set of learning resources for the learners, in addition to the economical considerations.

## **Conclusion**

This chapter has explored what kinds of learning resources are suitable for reuse and how they can be reused. This research issue is motivated by the increased use of digital learning resources in formal educational institutions and the corresponding interest in standards for educational technology for sustainable deployment of such resources. This issue has been addressed by an embedded case study of two semesters of an online introductory course on object-oriented programming. As a result of our analysis, we have suggested a tentative taxonomy of reuse. We have identified four levels of reuse: primary level (learning material), secondary level (course design components), tertiary level (course design), and quaternary level (pedagogical approach). Current standards for, and specifications of, learning technology are primarily concerned with reuse at the primary and tertiary level. The specifications discussed in this chapter do not address the secondary level explicitly. Quaternary reuse is mostly accomplished through literature on learning theories



expressed in natural language and, to some extent, in pedagogical patterns.

One central question regarding the introduction of standards in educational institutions concerns the kinds of learning resource to which such efforts should be directed. Currently, we have developed our taxonomy in the most detail at the primary level. Although we expect to develop the taxonomy of reuse through further research, we believe that it can, even now, prove beneficial as a guiding framework for educational practitioners and decision-makers who seek to facilitate the reuse of learning resources through standardization.

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