Sustaining Collaboration within a Learning Community in Flexible Engineering Education

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Abstract: This paper presents an innovative approach in flexible learning that can facilitate hands-on activities in engineering education. The approach focuses on the mediation role of artifacts within a learning community. The artifacts serve both as a medium and as a product of the collaboration process in the community. We have proposed the eJournal as a mediating artifact, which has been developed to support knowledge acquisition and reinforcement in a collaborative way. The eJournal is designed as a shared workspace that supplies different metrics for sharing, monitoring and evaluating the collaborative learning process in flexible hands-on activities. The eJournal is integrated into the Cockpit environment, which is currently used for various practical courses at the School of Engineering, Swiss Federal Institute of Technology (EPFL).

Introduction

The rapid development of the Internet in the last decade has provided new possibilities and also new challenges for designing and deploying distance and collaborative learning systems. Web-based experimentation turns to be a key feature in the deployment of e-Learning solutions for engineering education. It offers a tremendous opportunity to add flexibility in traditional curriculum by providing students with versatile access to the learning material from both a time and a location perspective (Gillet et al. 2003).

In laboratory sessions, engineering students learn by performing experiments and usually work in groups. The groups, the professors, and the assistants form a learning community with their own rules and norms. The collaboration between students themselves as well as between students and professors while carrying out an experiment facilitates the construction of knowledge. As indicated in (Andriessen 2003), learning takes place at different levels, and an important means of dealing with sharing, applying and developing knowledge is provided through learning community.

In order to sustain the flexible learning deployment, the Board of the Swiss Federal Institutes of Technology has launched in 2001 the ***eMersion*** project, which aims at providing a Web-based environment that supports hands-on experimentation through remote manipulation of physical laboratory devices and/or computer simulation tools. In the context of this project, we have developed the Cockpit environment, which is currently used in Automatic Control, Fluid Mechanics and Biomechanics courses at the School of Engineering, EPFL. The environment provides the student with the possibility to carry out experimentation in a flexible way, i.e. students can follow different learning modalities (Sire, Nguyen & Gillet 2003) to perform multi-session experiments.

We propose a new approach that could accelerate the learning process using Web-based environments that support hands-on activities. The objective is to determine 'how to better fit a Web-based environment for hands-on activities', 'how to encourage flexible work', and 'how to integrate a collaborative workspace into the flexible context of engineering education'. Those questions have resulted in our studies about the participatory, and the collaboration aspects of learning community in a flexible context. The examples presented in the paper are mostly based on the results from our studies and evaluation carried out during the 2003 academic spring term at EPFL.

This paper presents an innovative Web-based environment and deployment scheme that facilitate the hands-on activities in engineering education. Section 2 presents the learning setting and the Cockpit environment. Section 3 is about the theoretical fundamentals of the approach. In section 4, we present the new-defined types of awareness to support group-works. Section 5 and 6 present the evaluation and related work. The paper is concluded with future work.

Web-based collaboration learning environment for engineering education

The learning setting

In engineering education, the practical activities are as important as the theoretical ones. In the spirit of flexible learning (Gillet et al. 2003), students have the possibility of carrying out an experiment at any time and from a location of their choice; thus benefiting from a more effective cognitive experience. Even within a single experimental session, students can perform their work using different workspaces. Students can also perform multi-session experiments. This means, for instance, they can do the first part of the experiment at school, and pursue the rest at home. Briefly speaking, the student is provided with the possibility of following a flexible learning paradigm, which means that they can choose different learning modalities.

During the 2003 spring term, we conducted a full-scale deployment experiment with a clan of 96 students in Micro-engineering. The clan was split into different groups of 2 people using the Cockpit environment to carry out practical assignments in Automatic Control. These groups, plus the professors, the assistants, and all supporting resources formed a learning community. The students' work relied heavily on the learning community as their knowledge resource. The experimentation protocol was divided into two parts: the pre-lab and the lab-work. The student had to successfully fill the pre-lab forms because they posed technical questions that had to be answered to gain permission to access the given Web-based laboratory resources necessary to carry out the lab-work. The pre-labs were submitted to the assistant, and then evaluated. The course lasted for 14 weeks.

The Cockpit environment

The Cockpit environment contains all the components necessary to complete successful experimentation. These components are heterogeneous in the sense that they were developed using different technologies and may be located on different servers. The main components are as follows

- Experimentation component: it was developed as a Java applet and can be regarded as the interaction part that enables the actual realization of experiments.
- SysQuake Remote component: it is a PHP application, which provides students with tools to carry out interactive design and analysis activities related to the experiment. It embeds easily advanced computation and graphics such as parameterized graphics, graphical representations, etc.
- eJournal: this will be presented later.

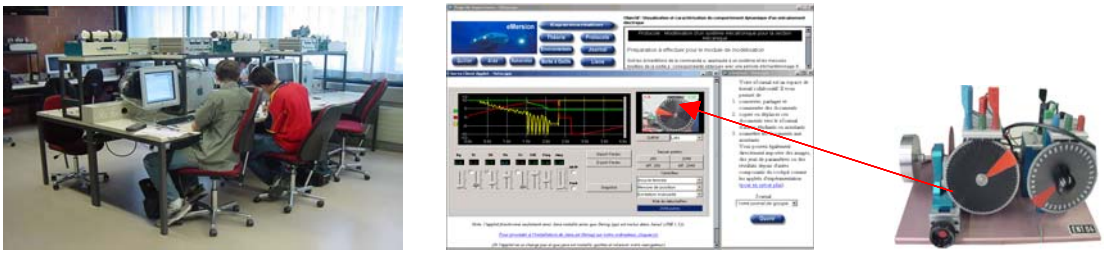

Figure 1: The practical course and the Cockpit environment for Automatic Control

In Figure 1, we can see two modes of working; students can work in the laboratory (face-to-face) or remotely using the same Web environment, namely the Cockpit. The figure shows the Cockpit environment for the Automatic Control module used in manipulating an electronic drive. The real electronic drive is visualized in real time using a webcam. Details of the environment are presented in (Gillet et al. 2003).

The eJournal

Background

The proposed approach is based on Activity Theory (Leontev 1978, Kuutti 1995, Adriessen 2003), which is a theory concerning human social interaction with tools, in the context of a community. It is a theory about human interaction and about work activities supported by artifacts. The idea is that humans can control their own behavior while creating and using the artifact (Kuutti 1995). Generally, an activity is a form of doing directed towards an object to obtain an outcome. Actions are performed by the subject. The relationship between the subject and the object is mediated by artifacts. However, an activity is only meaningful in a specific context, within a community. The relationship between subject and community is mediated by rules, which cover norms, conventions and social relations within the community. The relationship between object and community is mediated by the division of labor, which refers to the organization of the community.

Activity Theory really meets our context. It directs our research as well as our development. In our learning setting, students work in groups of 2 people. These groups, which form the subject of activity, plus the professors (also subjects of some activities), and the assistants (also have the role of subjects), who help students in the laboratory as well as via the Web environment, create a learning community. The student objective is to perform the experiments in order to obtain some knowledge, thus to be able to get their grades (their outcomes). The class (the learning community) has rules and the division of labor for everyone.

The artifact plays an important role in facilitating the learning process, especially in hands-on laboratory sessions. The Activity Theory has also stressed the mediation role of artifacts. According to Stahl's researches in CSCL (2002), an artifact is a meaningful object created by people for specific uses. Artifacts mediate knowledge building. Artifacts also mediate the interaction and interviewing of personal and group perspectives. Achieving a shared understanding of the meaning of artifacts among a group of people clearly facilitates group work. In our approach, the mediation role of artifacts is further investigated and applied in a real flexible learning environment. In the environment, most of the interactions pass through or result in some kinds of artifact. The artifact serves as a means for articulating distributed activities in the learning settings.

The eJournal description

In order to support collaboration among members of the learning community, we have developed the eJournal, which is integrated into the Cockpit environment. However, the eJournal can also be launched as a stand-alone application. The eJournal has been designed as an extended electronic version of the traditional laboratory journal, or laboratory notebook, which serves as a repository for experimental resources. Note that in out context, we will use the terms "notebook" and "journal" interchangeably. Students can also use the laboratory notebook to note their experimental motivations, experimental details, the process of scientific discovery, the procedures followed, the raw data collected, resulting data and their analysis, any ideas or observations as they occur, as well as thoughts on future directions (McCormack et al. 1991, Myers et al. 1996). Furthermore, the eJournal benefits from the collaboration aspect of papers (or paper-like instruments) in communities, which has been shown by many empirical studies (see Schmidt & Bannon 1992).

The eJournal provides a collaborative shared workspace, where students can store, share and exchange the group documents such as pre-labs, experimental results, etc. when performing the experiments. One can use the eJournal to upload documents from local disks, can import/export experimental parameters and/or numerical results from/to other Cockpit components such as the Experimentation applet or SysQuake Remote. This point is important in the sense that the eJournal, as a laboratory notebook, should support the experimental data input/output. Using the eJournal, students can also submit their documents such as pre-labs to the professor.

Different eJournal spaces are provided for working. The private eJournal space can only be read or modified by its group members, and the shared eJournal space is the shared space for other groups. The users can work on their private eJournal spaces before sharing them with others. Each group has its own eJournal. Authorization is provided depending on the user role and the context. Users continually shift back and forth between different spaces when working.

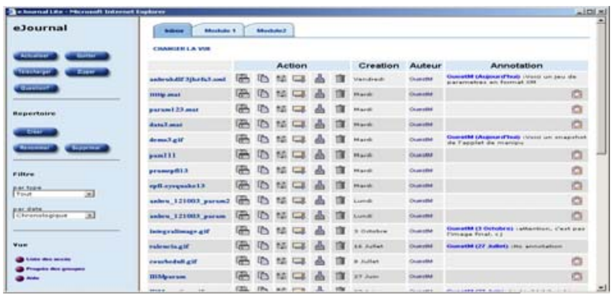

Figure 2: The eJournal interface

The concept of eJournal and its fragments as shared artifacts in learning community

The eJournal main space looks like that of Figure 2. We call the documents in the eJournal "fragments". The fragments are typed, representing different kinds of data (e.g. snapshots, parameters, experimental results, etc.). Fragments with different types are handled differently. The fragments are displayed chronologically. The fragments may be grouped into different folders. Properties can be attached to fragments. The fragments in the space can be filtered. They can also be deleted temporarily or definitely.

The fragments are considered as shared artifacts, which constitute the composite artifact (the eJournal), in our learning community. Using these kinds of shared artifacts, groups are provided with many different ways to collaborate with peers as well as with professors and assistants. Students can add annotations to the fragments, which will be viewed by other users. Students can directly send fragments, or send questions with attached fragments to other groups or to the group of assistants via an integrated email system. The eJournal also provides the possibility to copy/move fragments from one eJournal to another. In a normal situation, a student can send fragments from his/her own eJournal to another eJournal, or view fragments in his/her eJournal. However, there are also situations where a student logs into another eJournal (shared eJournal spaces) to get or view a fragment from that eJournal if they were granted the necessary permission. The collaboration activities, which are supported using the fragment as shared artifacts, are called "**fragment-based activities**".

In addition, the eJournal is a convenient medium for sustaining the continuity of interaction, which emphasizes the uninterrupted sequence of dialogue activities, thus, well supports collaboration among members of the learning community. This concept is quite important in the flexible context of hands-on experimentation. More discussions about the continuity of interaction can be found in (Nguyen et al. 2004).

The eJournal helps to sustain the collaboration between members of the learning community. It takes the role of mediating objects and facilitates the construction of knowledge well. It is considered both as a medium and as a product of the collaboration process in the learning community. In the next section, we will show that the fragments can also be used to provide awareness about the activities and the social structure of the community, thus offering an effective vehicle for learning monitoring and collaboration processes.

Group awareness

Awareness in a Web-based learning environment

Knowing the activities of other co-workers is a basic requirement for group interaction, which is the visible aspect of collaborations (Martinez et al. 2002). In a face-to-face condition, users find it naturally easy to maintain a sense of awareness about the activities of others. However, in other conditions, supporting spontaneous interaction is evidently much more difficult. To support effective collaboration, systems should provide group awareness, which is defined as "an understanding of the activities and progresses of others, which provides a context for your own activities" (Dourish & Bellotti 1992). Various awareness mechanisms have been produced to support group awareness (Gutwin & Greenberg 1996), such as tele-pointers, radar-views, or distortion-oriented lenses. Generally, the system gathers data about the students' interaction, and shows some visualization of this information to the user. It is then up to users to interpret the awareness and decide which actions to take.

In learning, awareness plays an important role in facilitating the learning process, especially in a flexible context such as ours. Professors need awareness to have a general view of the class activities, to monitor the class progress, to detect problems in order to intervene in time. Students need awareness to have a view about their progress compared to other groups. Awareness is also necessary for students to find potential collaborators for exchanging documents and ideas, and to ask for help. However, conventional awareness mechanisms do not cover all aspects of group collaboration in a flexible learning context. In other words, those mechanisms are not enough for monitoring the learning process in a Web-based learning environment.

One of the important phases of the monitoring process is to select one or more high-level variables, termed indicators, which can represent some states of collaboration among users in the learning community. We suggest a new approach to provide awareness based on the visualization of fragment-based activities. The fragment-based interaction is aggregated into some indicators and then displayed to the users. Some Social Network Analysis (SNA) methods will be applied to construct the social structure and to find the interaction patterns in the learning community. In reality, many works have demonstrated the usefulness of SNA for the study of interaction among different groups (Nurmela et al. 1999, Martinez et al. 2002, Reffay & Chanier 2003). Their works, however, only applied at the evaluation phase for the study of the participatory aspect of learning. SNA (Wasserman & Faust 1994) is an approach that focuses on the study of patterns of relationships between actors in communities. The SNA issues are located in the intersection of the sociometry, group dynamics, graph theory, and anthropology domains. Using SNA methods, one would seek to model the relationship that depicts the structure of the community. So one could then study the impact of this structure on the functioning of the groups within the same community.

Fragment-based awareness

We have developed various services that provide awareness about group activities in the learning community. Besides the availability awareness such as the user presence (who is currently connected to the environment), the user location (in the lab, at school, or at home), we also provide group awareness based on the fragment activities, which is richer than conventional artifact feedback or feed-through (Dourish & Bellotti 1992) in group and especially in community levels.

The permission-granted users can access the eJournal of others to view the annotations attached to fragments. The students can also see the group progress based on the pre-labs (whether the assistant has evaluated their pre-labs or not). This awareness is displayed in the form of a table, which contains the available modules, the allowed modules, etc. These are some basic features for getting knowledge about the others‘ activities and advancements.

From the environment, one can view the charts representing the fragments created by all groups (with many options such as “since last week”, or “since the beginning of term”). Different kinds of charts are proposed such as bar charts, or pie charts. By looking at these charts, one can get an idea about the advancement of each group and of the whole class. Our hypothesis is “*the awareness can be based on the fact that the more students create fragments in the eJournal the more they participate in the learning process*”. Figure 3 shows a bar chart (the left chart), in which one can see the number of fragments (y-axis) of all groups (x-axis) for the whole term. By clicking in an area representing a group in a bar or pie chart, one can see the fragment evolution, week-by-week, during all 14 weeks of the course (the right chart). This information could be useful to professors for understanding some student behaviors. For example, the peaks in line chart representing the high number of created fragments can be explained by the fact that students work harder before the assignment due date, especially before the lab test (the course exam).

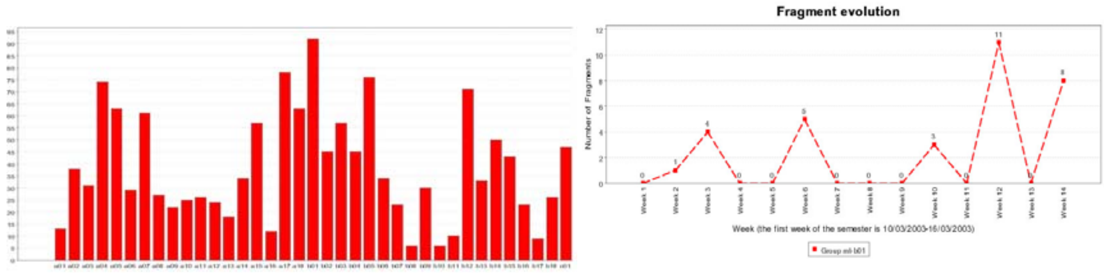

Figure 3: Charts represent the fragment contributions and evolution

We extract information from log data and use SNA approach to evaluate the social level structures and processes of groups using the eJournal. In fact, the log data is a convenient source, which can be used for data collection, for actions evaluation and feedback can be made available immediately to the learning community (Nurmela et al. 1999). The fragment-based actions of students in the eJournal are logged in a relational database. We have developed a simple tool in Java to extract log data from the database. The data is then used to create matrices, which are suitable for being processed by the UCINET SNA package (Borgatti et al. 2002).

Figure 4 is a sociogram representing the social structure of group collaborations. The sociogram is generated from the group-by-group matrix NxN (N=total number of groups), where x_{ij} represents the fact that there is an interaction between the group at the i^{th} row and the group at the j^{th} column. In the sociogram, nodes represent groups and lines represent the interaction between groups. We use different shapes and colors to refer to some special groups, the Staff group, i.e. the group of assistants who evaluate the students‘ pre-labs, and some groups from the previous terms (A4, B1, B8). This event is fairly interesting. It indicates that there are relations between different groups enrolled in different academic years.

For establishing the community structure, we are interested in those techniques giving information about structural properties of the network as a whole, and particularly, those related to cohesion, which is an important factor that motivates participants to accomplish the requested task (Reffay & Chanier 2003), to perceive and feel attracted to their own group (Andriessen 2003). In fact, as represented in (Wasserman & Faust 1994), to construct the social structure of a community, one should find the active groups, find the groups that are closer one to another, more connected one to another, and maybe the groups all connected one to another.

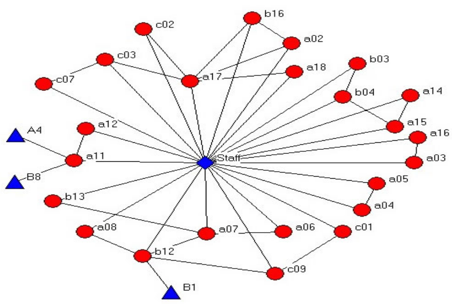

Figure 4: The social structure of group collaborations

To find community network substructures, i.e. the fully connected groups, cliques are detected (Wasserman & Faust 1994). The clique is defined as a maximal complete sub-graph. That means it contains a subset of groups, all of which are adjacent to each other, and there are no other groups that are also adjacent to all of the members of the clique. For example, Staff, Mt-a17, Mt-a02, Mt-b16 form a clique; Staff, Mt-a11, Mt-a12 form another clique.

Obviously, Staff is present in all cliques. It takes the most important role in facilitating the collaboration among groups. Its role could be considered as an animator. Besides Staff, the Mt-a17 group is the most active group considering the number of cliques in which this group participated.

We also calculate Freeman's centrality degree measure (Wasserman & Faust 1994), which gave the results presented in Table 1 (we have just shown some first and last groups). The centrality degree measures the total number of relations a group actually has. The "Relative degree" represents the percentage in centrality degree of all groups. The higher centrality degree a group has, the more active this group is in the community.

Group	Centrality degree	Relative degree
Staff	51.00	0.175
Mt-b12	37.00	0.127
Mt-a11	19.00	0.065
Mt-a17	13.00	0.045
Mt-a16	3.00	0.010
Mt-a03	2.00	0.007

Table 1. Freeman's centrality degree measure

The tables, the fragment charts, the sociograms and the social network measures give professors and students a general overview of active and passive groups in the learning community, as well as the structure of the community. This is what we call "**social structure awareness**". For example, one can see clearly that Mt-a17 is one of the most active groups, which has an important role in the knowledge distribution in the class. In contrast, the groups Mt-a03, Mt-a16 work rather passively. Then, professors and assistants can use the obtained information to decide what to do next; for instance, the professor can re-organize the class structure to facilitate the student learning process. Students can find their positions in comparison to the whole class, so they can be more motivated. They can also find the potential groups with which they can collaborate.

Evaluation

We have adopted a usability engineering approach (Rosson & Carroll 2002) for evaluation. This is preferred to a didactical evaluation because this evaluation takes place in an iterative design process with the purpose of improving the design of user interfaces as well as the pedagogical scenario. Other evaluation objectives are to verify whether the proposed approach could be a solution for the questions indicated in the Introduction. The evaluation of the acceptance aspect is based on a user-interface satisfaction questionnaire, which contains usability related assertions to which the respondent has to agree or disagree on a seven point scale, ranging from 1 (strongly disagree) to 7 (strongly agree). The second evaluation instrument relies on the analysis of the content of the database and the file system that holds the eJournals. We have defined different metrics (Sire, Nguyen & Gillet 2003) to verify our evaluation goals (participatory, flexibility and collaboration aspects of community). The last evaluation instrument is individual interviews with the volunteer students.

71 students out of 96 (74%) returned the questionnaires with a mean of satisfaction of 4.026 out of 7. This means that students are fairly satisfied with our environment. Every group created a mean of 36 fragments in performing the practical modules for the whole term. The participation aspect of evaluation was reached as all the groups created a significant amount of fragments. 86% of the fragments were created within the environment with the Experimentation component and the SysQuake Remote; the remaining 14% were fragments created with external applications. The number of fragments created in flexible sessions (occurs outside the laboratory) was 55%. This means that students accepted and already worked in different learning modalities. Many SNA methods and measures were calculated to verify the collaboration aspect.

We recorded about 225 minutes of interviews with 5 volunteer students. They all agreed that the eJournal had simplified their group tasks when performing the experiments and processing the results. They felt more comfortable when working in different spaces (Experimentation applet, SysQuake Remote, etc.) and physical places with the help of the eJournal. They also stated that the new form of awareness had an impact on their working behaviors. The awareness made their works more effective. Being informed about the others' advancement, they could accelerate their work or find collaborators to exchange documents, and to get help. We noted that the volunteers, who were motivated in using and exploring the environment, received very good grades in their exams. Surprisingly, the active group Mt-a17 received the worst grades. This may be explained by the fact that the students in this group did not have sufficient background for the course. So they needed to collaborate actively with others to get help.

Related work

Recently, there has been a growing interest in supporting collaborative work over the Internet. One of the best-known collaborative tools in academia is BSCW. This is a shared workspace where users can share information; collaboratively perform their activities over the Web. Other Web-based collaborative tools or architectures could be considered (Beca et al. 1998, Lee et al. 2000). However, because all of these environments are not designed for engineering education, remote experimentation is not supported.

The idea of electronic notebooks has also been investigated. Edelson et al. from Northwestern University have developed the CoVis Collaboratory Notebook (Edelson & O'Neil 1994), which is a shared, hypermedia database that supports communication and collaboration both locally and remotely over the Internet for high school science learning. It is mainly a medium for students to record their thoughts and actions as they perform scientific inquiry. PENS (Hong et al. 1994) is an off-line authoring client, which simplifies posting of Web information for both student and staff. It is used by the teaching staff for curriculum development notes and for posting FAQs to the Web pages of the Mechatronics System Design class offered by Stanford University's Department of Mechanical Engineering. The ELN prototype (Myers et al. 1996) developed at the Pacific Northwest Laboratory is a WWW based laboratory notebook that can support the needs of researchers wishing to develop and share a common repository of scientific knowledge. The ELN supports many types of input data, including audio and video, as well as analysis and presentation files. However, the main drawback when using those notebooks in the context of performing practical courses is that users must enter data manually, i.e. there is no mechanism for the direct transmission of data between the notebook and the experimental components.

In fact, all environments just presented do not provide enough awareness for mirroring and monitoring the activities of a learning community. It seems that there is no work that investigates the role of shared artifacts in sustaining the collaboration within a learning community in flexible engineering education.

Conclusions and future work

This paper presents an approach using fragments in an eJournal as shared artifacts to sustain the collaboration in Web-based engineering educational environment. The eJournal can be considered as an instrument to create and augment the interaction process; that means the collaboration among students, between professors and students. Based on the fragments in the eJournal, one can develop different kinds of tools and services, which provide awareness about the group activities, group progress, and the social structure of the community. The fragment-based awareness is richer than conventional awareness in group and community levels. This is really useful for professors and students in the learning process. The approach is based on Activity Theory, the notion of artifacts and its mediation role in a community. In fact, the approach does not require much in the way of resources, which are actually a constraint for distance and collaborative learning systems development and deployment.

The eJournal is currently used in the Automatic Control, Fluid Mechanics and Biomechanics courses at the School of Engineering, Swiss Federal Institute of Technology. We follow the iterative approach, in which the user feedbacks and our observations help to validate and develop our hypotheses and solutions. We would like to extend our studies on the impact of shared artifacts in an engineering learning community, especially in a flexible context. We would also like to develop a formal model for the analysis, design and development of artifact-based interaction in Web-based learning environments.

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