Web-Based Learning through Collaborative Design: Principles, Environment, and Activities[1]

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Abstract

We introduce in this paper a framework and guidelines for learning through collaborative design on the ever-popular Web environment. We first summerize important factors mentioned in previous constructivist theories and pedagogies and propose four goals for learning: Active, Simulative, Interactive/Inter-creative, and Accumulative, called the ASIA principles together. According to these goals, we developed an environment for collaboratively learning through design on the Internet. Here we describe the functionality of this environment, including a Vee-heuristic-based design interface, an on-line project management tool, and discussion channels. We then describe an exemplar learning activity with natural evolution as the learning topic. A simulation package was developed to realize the goal of learning by doing. We conducted an experiment to validate the environment. Based on the observation and evaluation of the experiment, we conclude that the pedagogical principles are plausible and the environment is effective in stimulating interests and innovation of students.

I. Introduction

The importance of cooperative or collaborative learning has become more and more obvious, especially in an era that students are living in a computer and network environment (Crook, 1998). Collaborative leanring, since its hand-shaking with computer-assisted learning (Hooper, 1992), distance learning (Thach & Murphy, 1994), and constructivism (Yakimovicz & Murphy, 1995), has found many ways to be embedded into learning systems (Silverman, 1995; Sun & Chou, 1996; Brush, 1998; Howe & Tolmie, 1998; Steeples & Mayes, 1998) in quite different manners.

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Recently, the integration of constructive learning and distance learning on a Web-based environment has been receiving more and more attention. For example, diversified on-line or off-line schemes have been proposed to realize collaborative learning, such as co-authoring and peer evaluation (Sun, 1999). The former is a desirable learning strategy that found strong support from cognitive sciences; the latter a viable and flexible playground to explore new knowledge frontiers. Accordingly, a new paradigm of learning theory, *Distributed Constructionism* (Resnick, 1996), has emerged to provide a fundation for developing suitable learning systems and strategies to fully exploit the educational potential of the Internet.

From the angle of distance learning, distributed constructionism can be considered a social and cultural process among a community of network learners. In essence, constructionism emphasizes the concept of *knowledge as consensus*. This viewpoint is rather different from that of some distance education providers who utilize the Internet primarily as a tool for information transfer and communication. While traditional pedagogy emphasizes on knowledge transferring and skill training, in a constructionist learning environment, knowledge is built up in interaction with others. This concept deserves to be fully explored in a network-based virtual environment.

Moreover, according to Resnick (1996), constructionism consists of two types of construction. First, it views learning as an active process of the learners who build up knowledge based on their experiences. In other words, they *make* ideas instead of *obtaining* them from the teachers. Second, when the learners devote themselves to realize products they feel interested in, they can achieve the best learning effect in terms of knowledge construction. In other words, *learning by doing* is highly emphasized in this new learning paradigm.

Based on the desirables proposed in previous constructionist articles, we summarize four goals to achieve, they are Active learning, Simulative learning, Interactive/Inter-creative learning, and Accumulative learning. We call them the ASIA principles for short.

First, active learning is essential in student-centered and project-based learning. As indicated by Steeples and Mayes (1998), the key benefits of collaborative learning include active learning and deep processing of information through requiring learners to invest mental effort.

Second, simulation provides a proper way to realizing learning-by-doing on a network-based environment. Although there exist other ways to encourage students to manipulating artifacts via the network, e.g., in a tele-presence on-line experiment, simulation represents an economical and reliable approach for instructors to design learning activities on line.

Third, the interaction between the participants of a collaborative learning session is so obvious that its phenomena and effects have been studied in various aspects in previous studies. Here we tried to proceed beyond the interactions implied by communication and coordination and to explore the new territory of inter-creation based on critical thinking and conflict resolution among the learning companions.

Finally, accumulation, or continuous knowledge construction, is another valuable asset of the web that should be fully exploited. From a system view, on-line design works can be maintained for future use by other students. More important, from a student's view, he can visit the same learning site later when he feels the need of re-learning the subject.

To realize the ASIA principles, we choose *collaborative design* as the core concept of learning activity because it put together the above goals in a natural way. Design as pedagogy was investigated in the past. A single student can learn from a design project not only the domain knowledge but also hands-on skills. This approach of learning by doing has been emphasized on certain fields such as engineering. On the other hand, learning design through teamwork provides even more benefits, such as communication techniques and learning companions' viewpoints (Murphy, Drabier, & Epps, 1998). Constructing a community of designers has become a promising method to achieve multiple goals at a time (Evard, 1996).

How a group of people work together to make decision is a sophisticated matter (Baron, Kerr, & Miller, 1992), especially in ill-structured context such as design (Sherry & Myers, 1998). Thus, it is important to provide appropriate communication and design tools to alleviate their burden. Various models of collaborative learning (Hartley, 1996) should be combined with up-to-date groupware for design tasks to meet this ever-demanding goal. Guidance and tools have been tailored to meet new requirements in new environments (Petrie, Cutkosky, & Park, 1994). In this respect the previous studies on computer-supported cooperative work (CSCW) should provide useful insight and experience for learning system development (Olson, Card, Landauer, Olson, Malone, & Leggett, 1993).

Distributed constructionism provides an integrated view of the above goals and it can be discussed at three levels: discussing constructions, sharing constructions, and collaborating on constructions. Consequently, a large amount of structure is needed for students to exchange information and ideas. To realize the essential concepts in this theory, we developed appropriate tools, interfaces, courseware, and learning activities. To construct learning activities has many facets to consider (Webb, Troper, & Fall, 1995). For example, the role of *critical thinking* in collaborative learning has long been pinpointed (Adams & Hamm, 1990). In this environment we can then conduct instructional experiments in which learning processes are appropriately structured, guided, and analyzed.

In this framework, items for analysis include dialogue patterns (Bodzin & Park, 2000) or communication patterns (Gay & Grosz-Ngate, 1994), learning flow and portfolio (Chang & Chen, 1998). Since team is one of the core concepts in collaborative learning, team-forming and its consequences have been explored in the past, such as heterogeneous versus homogeneous grouping (Hooper & Hannafin, 1988). The dependent variables studied include acheivement, interaction, learning efficiency (Hooper & Hannafin, 1991), time on task, and satisfaction (Klein & Pridemore, 1992).

II. System Description

In this section we first describe the framework of the learning system and the design of the learning interface. We then introduce the experiment design and schedule followed by important results and discussions.

The framework of the collaborative learning through design environment is depicted in Figure 1. It is composed of three components: user interface, management interface, and file system. The user interface can be further divided into two parts: inter-team interface and intra-group interface.

Insert Figure 1 here.

In the following we briefly introduce the functionality behind this group-design interface. Figure 2 depicts the web page of the collaborative-team-based scientific activity design. After registering onto it, users can start collaborative activities.

Insert Figure 2 here.

The learning system supports functions such as an experiment registration module for the teams to log on. To encourage collaboration on various levels and manners we provide an intra-team peer assessment area where participants can demonstrate their work and comment on that by other teams. Just like most existing cooperative learning environment, the system has a chat room and a BBS for students to discuss with each other synchronously or asynchronously. There is also a bulletin board on which the system manager can post administrative information. And we include an exemplar project for students' reference to learn the details of developing a scientific activity collaboratively on the web.

At the beginning of an experiment session, the students log in the system after having their identities verified. Then, they will enter the collaborative design interface, as shown in Figure 3. The experiment interface contains two parts: a function bar and an experiment procedure. The function bar indicates four working areas: intra-team peer assessment, inter-team chat room, BBS, and back-to-home.

Insert Figure 3 here.

One of the contributions of this project is to enhance the static Vee diagram with the concept of design flow. As introduced above, the Vee heuristic emphasizes on concept interplay. A proposed hypothesis should have strong theoretical support, and should be verifiable based on observable items. For a single designer working alone, he or she can shift between possible theories and observable checkpoints. This working style is flexible at the possible expense of systematic approach. On the other hand, for a team to work toward a group project, coordination is an essential factor during the process. To efficiently arrange a limited period of time, the participants need a carefully scheduled design plan so that they can focus on a certain subject at a time. Thus, we explicitly divide the Vee framework into five stages, as seen in Figure 4.

Insert Figure 4 here.

The first stage is to identify a question to ask and a number of items to observe which is closely related to the focus question. Secondly, the team members need to collect and organize theories and concepts that form the basis of the addressed issue. Next, in the third stage, a complete activity should be articulated to prove the proposed hypotheses. Then, participant should predict possible outcomes of the experiment based on the itemized observable entities, and argue the validity of the experiment. Finally, a team should analyze and conclude their design, based on inter- and intra-team discussions, and summarize their primary findings in a web report.

Figure 5 depicts the working area for the members of a certain team. It includes important functions such as uploading reports, passing messages, displaying designs, assessing other projects, chatting with partners, participating in BBS, and so on. On the upper-left area for navigation guidance, a student can check design pieces by his/her partners, as well as their comments and suggestions via the message system. On the other hand, students can use the lower-left command area to upload files, to paste team products to the public board for other teams to evaluate, and to send messages to partners, etc. Finally, in the right-hand-side window one can open a file and view the content in it.

Insert Figure 5 here.

This innovative learning environment benefits not only the students but also the teachers/researchers. For instance, an education investigator can observe the design and discussion processes both quantitatively and qualitatively without interference with the teamwork. Furthermore, when unbalanced discussion or workload sharing are found during an experiment session, the instructors can play a more active role to help solving the problems before they further damage the collaborative work.

The URL of the above web site for learning through collaborative design is as follows: http://sandy.cis.nctu.edu.tw/~colearn/page1.html.

III. Experiment and Results

Experiment Subjects

We have conducted two experiments on college students. Our subjects were undergraduate students of National Chiao Tung University. The first experiment involved 155 students from an Introduction to Artificial Intelligence class, fall 1998, and the second involved 36 from an Evolutionary Computation class, fall 1999.

In the AI class given by this author, a focus question was assigned for the student groups to investigate. The question is: Assume you are a member in the Star Fleet, develop a procedure for judging the existence of intelligent lifestyles on a target planet. Obviously this is an ill-structured open question that has no ready or standard answers to it. On the other hand, the students on the EC class are told to propose their own focus question related to evolution theories. On-line courseware on natural evolution and a Java-based simulation package was provided to this EC class and the students are asked to utilize the simulation tool in their scientific activity design.

In the following we report the primary observation of the first experiment on the AI class.

Team Forming

We employed the team-forming algorithm described above to partition 155 students enrolled in the AI class into 51 teams, with three members in 49 teams and four members in 2 teams. At the beginning of the experiment, all students were asked to fill an on-line thinking-style questionnaire (Lin & Chau，1999). Think style features were extracted from the questionnaire and used to form 26 heterogeneous teams and 25 homogeneous teams. By heterogeneity of a team we mean that the members in the team are different from each other in terms of the five thinking style elements: Executive/Legislative/Judicial and Internal/External. On the contrary, a homogeneous team has its members more or less similar in those aspects. Of course, the discrimination between heterogeneity and homogeneity is a matter of degree and has no clear cut.

Experiment Schedule

The experiment was conducted from 12/07/98 to 12/18/98, a 12-day period. It was divided into four stages: (a) 12/07~12/08: registration and posting the topic; (b) 12/09~12/12: discussing related concepts and designing procedure; (c) 12/13~12/16: predicting possible consequences and discussion; (d) 12/17~12/18: finishing and concluding the experiment. In this paper we report the primary observation of the first experiment.

After the experiment finished, the designed activities are evaluated by the instructor and two teaching assistants. The assessment is based on the creativity, comprehensibility, and plausibility of the proposed method. Next, we analyze the relationship between the design results and the team-forming attributes. Moreover, during the experiment session, comments to improve the system are taken into account in a constant manner. If an immediate modification does not affect the tempo of the experiment, it is adopted as soon as possible.

Important Experiment Results

For the above experiment conducted on the AI class, we proposed three research questions beforehand, they are:

1. According to the assessment on creativity, comprehensibility and plausibility, which type of teams (heterogeneous vs. homogeneous) perform better in terms of quality of design in this web-based cooperative learning situation?

2. Which type of teams (heterogeneous vs. homogeneous) receive more positive feedback from their members in terms of mutual evaluation among team members, collaborative process, and the learning-through-design environment?

3. Participants in which type of teams (heterogeneous vs. homogeneous) prefer to

work with their current partners in future learning?

And the primary findings are as follows:

1. The homogeneous teams performed better in terms of quality of design, according to the assessment on creativity, comprehensibility and plausibility, in this web-based cooperative learning situation. This piece of finding is different from some results reported in previous research concerning homogeneity of team members. One possible explanation, according to the investigators' observation during experiment and afterward interviews with the participants, is that heterogeneous teams in general need more time to construct a positive pattern for interaction and cooperation. Since our experiment period was pretty short (12 days during a semester) for a project-based learning assignment, those heterogeneous groups might not have enough time to build up chemistry.

2. Both types of teams gave positive opinions toward the system functionality. They both appreciated their teammates, the design goals, the design process, and the design results. In summary, they thought positively about this collaborative learning-through-design environment and were willing to involve in future activities.

3. Participants in heterogeneous teams were more willing to work again with their current partners in future learning projects. As Sternberg (1998) has indicated, members with different thinking styles tend to have better cooperation. In this study, we found that the attitude of heterogeneous teams might re-confirm Sternberg's theory, but the performance of them may need more time to fertilize.

IV. Concluding Remarks

In this paper we introduced a web-based learning environment which supports an innovative learning strategy by means of collaborative design. We described the system modules and their interface design and functionality. Two instructional experiments have been conducted. The procedure and results of one experiment on an AI class was briefly summarized and discussed as an example to demonstrate the effectiveness of the proposed learning strategy. Based on the theoretical study and experimental observation, we found that the constructive learning, collaborative learning, and network-based learning embedded in this learning environment have a great potential to improve learning, not only in terms of the design skill but also in stimulating students' active mental setting and creativity. This approach is worth further investigation.

The analyses up to this point have been largely quantitative. In the future we should emphasize more on the qualitative aspect so that the nature of heterogeneous collaboration can be further studied. We are now data-mining the conversation patterns and management mechanisms developed in different types of teams. In particular, we should find the relationship between students' behavior and their categorization from the thinking style questionnaire. Hopefully, we will report more about student interactions in this environment.

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