Developing a Technology of Use for Collaborative Project-Based Learning

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Abstract: We have designed and developed technologies to make it simpler for teachers and students to take educational advantage of the WWW for collaborative project-based learning. Recognizing that technologies alone are insufficient to effect educational change, we have also directed considerable effort toward working with teachers to construct principled understanding of what supports are required to make effective use of our technologies–a "technology of use." This paper describes the technology we have provided for teachers to support collaborative project-based learning, and through examples of one teacher's experiences with three Zebu projects we illustrate the needs and challenges in supporting more effective use. Building on what we have learned about supporting teachers in designing, planning, and implementing project structures that will support students in engaging in collaborative project-based learning, we have been working towards the design of a technology of use. This technology of use includes a representational scheme for helping teachers to portray, analyze, plan, design, share, and implement collaborative projects.

Keywords: project-based learning, scaffolding, teacher professional development

Introduction

The Internet and WWW are being used more and more frequently in classroom settings for education (Becker, 1999). However, few teachers are using the Internet and WWW for student projects beyond finding information–communicating with others, publishing work, or collaborating on projects (Becker, 1999). We have been working for several years on designing and developing technologies to make it simpler for teachers and students to use the WWW for collaborative project-based learning. This work has been based on the premise that conventional Internet technologies are inadequate for supporting the kinds of knowledge processes necessary for students to take full educational advantage of the WWW in project-based learning (Ward & Tiessen, 1997a; Ward & Tiessen, 1997b; Ward & Tiessen, 1999), to support the processes which we believe are critical for collaborative project-based learning within a community of learners.

Recognizing that technologies alone are insufficient to effect educational change, we have also directed considerable effort toward working with teachers who use our technologies to understand what efforts are required to make effective use of the technologies–a "technology of use" (Scardamalia, 1994). Scardamalia defines technology of use as "a technology that derives from scientifically guided experimentation in the use of new computer-based tools, resources, and environments to maximize educational outcomes," and claims that developing technologies of use is essential if technologies are to have positive effects for education. We suggest that it is also critical to develop such technologies of use to address issues of scalability and replication for widespread adoption of educational technologies. A technology of use would not be a simple pattern or recipe to be repeated, but a principled approach to understanding, communicating, and designing effective uses of a technology, which would support a community of teachers in addressing their challenges in applying a technology to solve educational problems.

This paper describes the technological supports we have provided for teachers to support collaborative project-based learning, and through examples of one teacher's experiences with three projects we illustrate the needs and challenges in supporting more effective use. We describe a simple representational tool which we have created to support the evolution of a technology of use for designing and implementing effective online projects.

Support for the Processes of Collaborative Project-Based Learning

We have developed a technology designed to provide support for the group communication and knowledge processes which we believe are critical for collaborative project-based learning within a learning community:

- **engaging in research and adding intellectual value to existing information resources**. This implies a shift from students acting as passive recipients of knowledge presented to them, to students actively engaging in sense-making and knowledge construction activities. By purposefully using information resources to construct answers to their own questions and achieve their own learning goals, students move beyond "knowledge reproduction" to "knowledge building" (Scardamalia & Bereiter, 1993) Within a community of learners, the shared representations that students create of the knowledge they are building, inherently add intellectual value to the original information resources (Brown et al., 1993).
- **sharing information and communicating to coordinate activities and to collaborate in building communal knowledge**. Within a community of learners, the focus is on the construction of knowledge representations and the learning that results from this construction. There will naturally be a variety of group processes at work as the community works to construct knowledge together (Brown et al., 1993; Rogoff, Matusov, & White, 1996). Communication–the sharing of information–creates mutual understanding and shared knowledge (Dix, 1994; Schrage, 1990). Cooperation–which requires communication–is the process of working together toward some shared purpose, generally the construction of some shared artifact (Dix, 1994). Collaboration is the process of creating new

knowledge and involves communication through a shared artifact for the sake of creating new understanding that the participants could not have achieved on their own (Schrage, 1990). All three of these processes–communication, cooperation, and collaboration–involve learning. In communication, it is the learning associated with developing shared understanding with others. In cooperation, students learn as they communicate to work together toward some shared purpose. In collaboration, learning results from the social construction of knowledge.

- **engaging in sustained progressive inquiry**. A characteristic of a learning community is that it engages in ongoing discourse. Such a discourse involves the exchange of ideas but, more importantly, building on the ideas and knowledge within the community (Bereiter, 1994). Within the classroom (or other educational context), such a discourse requires that students be engaged in sustained activities, that is, working on problems and goals that require substantial time and collective efforts to address. As part of these efforts, students must build on their own work and that of their peers to progressively advance their individual and group knowledge as they work on these problems and goals (Rogoff et al., 1996; Scardamalia & Bereiter, 1989; Scardamalia & Bereiter, 1996).

In the design of Zebu, our groupware technology, we have attempted to build specific supports for these knowledge processes as well as tools for teachers to support and scaffold student work within an integrated environment. Student work is automatically organized into group *projects* in which whole classes or several classes can participate. Through the project structure, students' work is automatically shared and students have access to each other's work in progress throughout the duration of a project. Students' work involves the construction of *pages* of multimedia *objects*, including text, graphics, sound, video, and links. Collaboration between students is supported through the co-construction of these pages. Within pages and projects, text-based *discussions* can be embedded to support communication. Additional tools (*reference collections* and *galleries*) for collecting, organizing, and sharing multimedia and information resources support research activities and information sharing. The ability to access and link to each other's work, makes it possible for students to use the contributions of other students to progressively build representations and artifacts within the project.

The processes involved in collaborative project-based learning can be supported and facilitated by the teacher who can structure the project space by setting up learning activities to achieve particular educational goals. The software itself does not provide scaffolding, but rather, makes it easy for teachers to provide scaffolding for students in several ways:

- Teachers can provide students with *templates* with which to create their own pages. Hence, students are not facing a blank page when starting their work. For example, if students are researching and writing about different animal species, the teacher can provide students with some structure of the appropriate multimedia objects that should be included in the students' work. The teacher can make this structure quite rigid and not allow students to change it, or keep it quite flexible and allow students to change different object attributes such as labels,

media types, and content. The teacher may choose to initially provide a great deal of structure within templates and then gradually decrease the amount of structure and give students more flexibility.

- When teachers create templates for their students, they can provide some scaffolding within the objects themselves to help students construct better representations. For example, if students are to write an explanation of a process, the teacher can provide them with some description of how to write a good explanation. Again, teachers can provide as much or as little of this support as they want.
- Teachers can scaffold communication between students. At one level, communication is facilitated through the shared project structure. When students contribute pages which they have constructed from teacher-created templates, the template structure acts as the means by which the teacher scaffolds how students communicate their work to each other. Another way in which the teacher can scaffold and support communication between students is through discussions. The teacher can set up discussions for students to brainstorm, answer questions, solve problems, or coordinate activities. The teacher may even provide specific guidelines for appropriate student interactions within these discussions.
- Teachers can provide scaffolding for students' use of information resources. Using reference collections, teachers can provide students with information resources to help students in their own investigations. Links to reference collections can be embedded in pages and templates, making it easy for teachers to provide specific information resources for students' activities. As students become more proficient in working with and finding information, teachers can turn this work over to students who can use these same tools.
- Teachers can provide the support needed to sustain student inquiry and help it to progress. While the project structure makes it possible for students to have ongoing access to each other's work, it is up to the teacher to support students in building on their collective work. This is done by designing learning activities within the project that help students to make substantial individual and group contributions to whole group goals, are rich enough to sustain student engagement over an extended period of time, and are interrelated so that students have reason to and can benefit from looking at and building on the work of their peers.

Support for Teachers

Despite the supports which have been provided within the software, our experience has been that students do not necessarily engage in these knowledge processes and teachers do not necessarily know how to take advantage of the software to support and facilitate student engagement in these processes. It has been helpful to examine how the software has been used with various levels of support for the teacher, to see where problems lie that make it difficult for teachers and students to use it to its full potential. As an example, we describe here one grade seven teacher and her students' use of Zebu for three projects over one school year.

First Project

The first Zebu project completed by this teacher and her students was called "Space Mysteries." The teacher structured the project with three learning activities: research about a planet, unmanned space travel, and manned space travel. For each of these activities, the teacher created a template to guide students' research. The templates contained minimal structure: for example, the planet research template provided objects for students to include information about the planet, a picture of the planet, a comparison of the planet to the next closest planet, a reference collection link for students to specify their sources of information, and a discussion about what would be required for humans to inhabit the planet. Within the templates, the teacher provided minimal guidance to students: for example, "Describe the characteristics of this planet" was the guidance provided for students to describe the planet. The teacher did not provide students with any information or multimedia resources within the project. In implementing the project, the teacher did not specify any structure for how students were to work together within the project using these templates, but simply that students were to begin with planet research. In examining the resulting project artifacts, there is little evidence that students did more than share their work with each other. Students began the project by using the planet research template to create their own page about a particular planet. Most of the content created by students consisted of facts about the planets copied from books. Some students completed their planet research and also created their own pages about unmanned and manned space travel. As a result, the project contained a large number of pages about the planets, many of them redundant, as well as several redundant pages about space travel. Hence, while there was communication of students' research to each other through the automatic sharing within the project structure, there was little or no group effort invested in constructing the overall project. There is evidence that the students looked at each other's pages: students made some contributions to discussions within each other's pages. However, because of the way in which the students created pages within the project, the same discussion question was duplicated in each student's page. The students used the discussions to respond and give feedback to the authors of the pages rather than discuss the given question.

Second Project

The second project in which this teacher and students participated was a project about endangered species. This project was created for the teacher and her students and was set up for them to participate with another teacher and students at a distant site. The project had been designed to involve students in a variety of interrelated activities including researching species, researching habitats, investigating reasons for endangerment, and developing potential solutions and plans of action. As well, the project was designed to have students work together using a variety of participant structures including individuals, pairs, small groups, and the whole group, with some groups comprised of students from both sites. The project provided students with several templates from which to generate their own pages, pages to support the whole group activities, and reference collections for students to find information to help them in their research and investigations. The project had been designed for the activities to build on each other: students were to work in pairs to research different plant and animal species in their own

region, leading to small group investigations about the regional habitats in which these species live and interact, and leading ultimately to whole group and small group activities about understanding reasons for endangerment common to the two regions. An additional "progress" template was provided for students to monitor and report on their own learning throughout the duration of the project. Unfortunately, in implementing the project, the teacher did not coordinate the students or the activities to be used as designed. The intention was that a variety of endangered species from the local region would be specified and pairs of students would take responsibility for researching one of these species. Instead, students each started their own progress page and their own page on an animal species from somewhere in the world. As a result, the project contained a huge number of pages about animal species from around the world, some of which were redundant. This made it difficult to progress to the next level of the project (i.e., researching habitats), as there were pages about only animal species and there was no common set of habitats amongst the species on which to base the next activity within the project. Neither class completed any further activities within the project.

Third Project

For the third project, we spent time with the teacher planning the project activities as well as how students would participate in the activities. This project, which focused on Pacific Coast ecosystems, engaged students in similar types of research activities as the first two projects, and also involved students in working together in different group structures on multiple interrelated activities. Several project pages were designed specifically to support these group activities. A project overview page presented students with the curriculum outcomes for the project, some contextual information about the project, a graphical organizer of the different types of coastal ecosystems, and a discussion for students to ask and answer questions about the project. A set of small group pages were set up for groups of students to work together on researching one of the coastal ecosystems. Within these pages, a structure of multimedia objects corresponding to curricular outcomes was provided to the students. Additional guidance was provided for each of the objects. For example, in the object in which students were to "identify chemical reactions that are important in the environment", additional guidance, "These may include the effects of the following on the ecosystem: oxygen, carbon dioxide, solubility, photosynthesis…" was provided to the students. A final page also supported a whole class activity in which students were presented a food web and asked to compare it to the food chains from each of the different coastal ecosystems by looking at the food chains created by students in the corresponding pages. A reference collection with a variety of information sources was provided to help students in their research. A link to this reference collection was included in the student pages, as a well as a link for students to create their own reference collection. In implementing the project, the teacher split the class into groups and assigned each group to work on one of the ecosystems. Students used the overview page to post questions and respond to questions from other members of the class. The small groups of students worked together to construct their pages on the different coastal ecosystems. Within these pages, they included textual and graphical representations of their work. Most of the groups also constructed reference collections of the information resources they collected and used in their research. As well, some students participated in the final group page in comparing their food webs, although the

class ran out of time to complete this activity. The project contents show a fairly complete body of student-generated work centered around understanding of different aspects of coastal ecosystems.

Summary

Within these three examples, there were different levels of support provided to the teacher and different levels of success in how students were able to engage in the knowledge processes of collaborative project-based learning as described above. In the first example, there was essentially no support to help the teacher effectively design and implement the project activities. While students were engaged in some research and shared their work, there is little evidence that they were engaged in adding intellectual value to existing resources, collaboration, or sustained progressive inquiry. In the second example, the learning activities had been designed for the teacher, but little support was provided to the teacher in effectively implementing the activities. Without any assistance, it seems that the teacher was unable to provide the students with the necessary support to advance the project beyond the initial research and sharing of information about different species. With the last project, support was provided to the teacher to plan, design and implement the project, and we saw more evidence of students participating in the knowledge processes of collaborative project-based learning (as described above). Students were engaged in research; however, rather than simply copying facts and information, they worked together in their groups to organize and synthesize the information according to prescribed learning outcomes. During the course of the project, students shared their work with other groups, worked together within their groups, and worked together as a whole group. The whole group activities gave students the opportunity to see and build on the interrelationships between their small group work.

Technology of Use for Collaborative Project-Based Learning

From our experience, teachers can learn to use the functions and features of Zebu with little assistance. However, as seen in these examples (and others), teachers do not necessarily have the understanding or ability to effectively use the technology to design and support effective collaborative projects. Teachers often require scaffolding and support to develop their abilities to design, develop, and implement online collaborative projects that will engage students in the knowledge processes described above. Through our work with teachers and students, we have been developing a better understanding of the type of support that teachers require. We have designed new technical supports to address some of the problems which we have observed in classroom use of Zebu. We have also been working on developing "technologies of use" for helping teachers to design, build, and implement project structures which will take better educational advantage of our technologies. Clearly, it is impossible to provide individualized support to more than a handful of teachers, and we must look to alternative ways to address the problem of supporting them. By working with teachers to develop a technology of use for our software technologies, we hope to support a community of teachers in which the discourse further advances the educational use of our software technologies.

From the initial attempts of many teachers to build project structures, it is evident that they do not have difficulty in conceiving of single project activities, or even several single project activities; this is somewhat analogous to conceiving of and designing lessons. The difficulty seems to lie more in building interrelated, progressive activities and to support effective group processes (communication, cooperation, collaboration) between students as they work on these activities. This is the problem of conceiving of and designing entire project plans. Just as the lesson plan has become a tool for teachers to conceive, design, and share lessons, we believe that teachers need a tool for conceiving of, designing, and sharing entire projects. In the design of a technology of use for designing, planning, and implementing project structures that will support students in engaging in collaborative project-based learning, two of the questions we have tried to address are:

- **how do we help teachers to (understand how to) make effective use of a variety of appropriate participant structures within collaborative projects?** We believe that this is important to facilitate the authentic sharing and communication between students necessary for sustaining progressive inquiry. As well, using a variety of participant structures within a project gives students the opportunity to take on individual and group responsibilities for their own learning and the learning of the whole group.
- **how do we help teachers to (understand how to) build sets of interrelated learning activities that will engage students in sustained progressive inquiry?** At the heart of sustained progressive inquiry is the notion that the work of the group advances. Hence, students need to have the opportunity to build on their own work and that of their peers. The project provides a means for students to have access to each other's work, but activities within the project need to build upon each other if students are to have reason to use each other's work.

Building on what teachers seem comfortable with, our starting point in designing a technology of use has been the single learning *activity structure* as the building block for larger project structures. In building a technology of use, we have been working on ways for teachers to construct activity structures from *activity components* that correspond to curriculum outcomes (this will not be addressed in this paper). Part of the process of designing activity structures is deciding the most appropriate participant structure for the activity. To address the first question, we have decomposed participant structures into individual, pair, small group, and whole group structures, and provided a simple representational scheme for teachers to specify a participant structure for individual learning activities which they are designing (see Figure 1). By specifying a participant structure to correspond to an activity component, consideration can be given to the most effective type of group process for achieving the learning goal of the activity.

Figure 1. Participant Structures

To address the second question, we have introduced the notion of *activity transitions* to help teachers consider how to build interrelationships between single learning activities and the participant structures these learning activities employ. These activity transitions include join, split, recombine, rotate, and regroup, and we have provided a simple representational scheme for these as well (see Figure 2). By specifying activity transitions between activities, attention can be given to the relationship between consecutive learning activities. For example, joining can be a way for students to bring unique work done in smaller groups to solving a problem within a larger group. As another example, splitting can be a way of distributing a set of problems or issues identified within a larger group to be investigated by different smaller groups. For these transitions to make sense, the consecutive activity structures need to be related in a way which supports the transition between the activities.

Figure 2: Activity Transitions

Although the transitions are identified as changes in participant structures, thinking about activity transitions is intended to support teachers' thinking about how whole project structures can be created from sets of interrelated activities. Using these representational schemes, one can construct project schematics which are essentially representations of projects along a timeline. We believe that these schematics can be useful for portraying, analyzing, planning, designing, sharing, and implementing projects.

Using Project Schematics

Project schematics can help to illustrate the structure of the project and highlight aspects of the project design such as the group supports and the flow of activities within the project, allowing us to clearly see important differences between projects. Figure 3 shows the schematics corresponding the three example projects described above. In the first project representation, we can see the same participant structure utilized for all three activities and with no transitions between these activities. In the second project schematic, we can see a much more complex project design. However, in looking at how the project was actually implemented, we see the same structural pattern as in the first project. The third project shows a flow of participant structures and transitions between the activities within the project. These project schematics can be used to formulate answers to such important questions as whether there are sufficient learning activities to sustain the project over a substantial period of time, whether students will have the opportunity to engage in a variety of group learning processes with their peers, and whether there is opportunity for students to build on their own work and that of their peers.

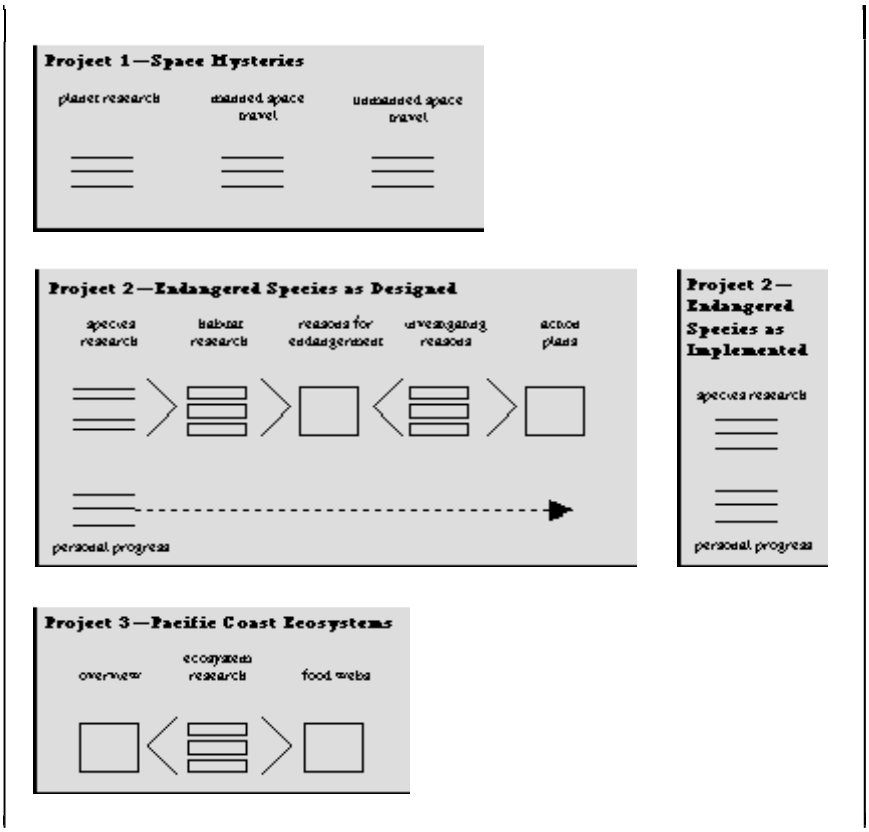

Figure 3: Project schematic representations

We believe that these project schematics can be used for more than descriptive purposes. We hypothesize that providing teachers with these representational schemes will help them to design and implement effective learning activities and project structures that

better support collaborative project-based learning. By using these representations during the process of designing and planning projects, we expect that teachers will be more likely to employ a variety of participant structures, design learning activities to take advantage of particular participant structures, and consider how to transition between the activities within the project and build interrelationships between them. Beyond facilitating planning, the resulting representation becomes a "blueprint" or plan for implementing the project and can be used for monitoring the progress of the project. We have been designing, building, and refining teacher workshop materials to utilize these representational schemes for project planning, designing, and implementing.

We are encouraged by our initial use of the project schematic tools with teachers. Through early use of these tools with teachers, we have been able to make refinements to them. In workshop settings, our informal observations indicate that they seem to help teachers in learning how to conceive and design projects for their students. As well, teachers have given us positive feedback about the tools.

As well, we would like to see these representational schemes become a means of communication within a community of teachers using our technologies, providing teachers with a "language" for easily communicating and sharing their best practices with other teachers. With Zebu, teachers can share projects which they have built for their students with each other. However, we know (and it can be seen in the second example above) that providing teachers with a ready-made set of project activities is not sufficient for the project to be effectively implemented. The project schematic becomes a way for teachers to visualize the entire structure of the project, the interrelationships between the activities, and how to coordinate students to work on the different learning activities within the project. By sharing these project representations along with the project contents, teachers can share both the artifacts and descriptions of their best practices with each other.

Further Research

Our next steps involve more formal investigations of the use of these tools over an extended period of time. In examining the value of these tools for conceiving, designing, planning, analyzing, implementing, and sharing projects, we would like to address the following questions:

- How effective is this representational scheme in helping teachers to conceive and design "better" project supports for their students?
- How can we best use the project schematics to help teachers to reflect on and advance their abilities to design "better" projects?
- How effective are the project schematics for helping teachers to monitor and manage projects as their students work on them?
- How effective are the project schematics in helping teachers to communicate their projects to each other?

Answering these questions will help us to further refine both our technology and technology of use and address the problem of how to help teachers to take full advantage of the Internet and WWW for supporting collaborative project-based learning for their students.

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