Influence of Authority on Convergence in Collaborative Learning

Teresa Hübscher-Younger and N. Hari Narayanan

Intelligent and Interactive Systems Laboratory
Department of Computer Science & Software Engineering
Auburn University, Auburn, AL 36849-5347
{teresa,narayan}@eng.auburn.edu

ABSTRACT

Teachers and students have established social roles, norms and conventions when they encounter Computer-Supported Collaborative Learning (CSCL) systems in the classroom. Authority, a major force in the classroom, gives certain people, objects, representations or ideas the power to affect thought and behavior and influences communication and interaction. Effective computer-supported collaborative learning requires students and teachers to change how they understand and assign authority. This paper describes two studies in which students' perceptions of authority led to learning difficulties while they were engaged in collaborative learning. Students converged on either a representation or representational style that they believed was authoritative instead of basing their choice on how well the available representations communicated a concept. Methods to help students avoid such premature convergence are suggested.

Keywords

Collaborative learning, authority, power, algorithm learning, computer-science students, college students, classroom

INTRODUCTION

It is often assumed in CSCL research that student ideas, understanding and communication styles are diverse, and that collaborative learning succeeds when the group can converge on a common understanding of a problem or concept. Students are assumed to be like scientists, looking at problems and concepts from different positions initially. Different understandings and knowledge are supposed to exist naturally in the student body.

On the other hand, often it is assumed that normal classroom practices are based on an information transmission model, where teachers present information to passive students. These two assumptions are mutually inconsistent. If all students obtain information primarily by absorbing it from one source, it is unlikely that they will have different knowledge and ideas.

The truth is found somewhere between these two positions. Students do differ and do not absorb information in the same way. However, they are often working with a similar set of assumptions, acquired from the same source. Students and teachers operate under a social system with methods for assigning, recognizing and understanding authority that makes it difficult for diversity to be recognized, acknowledged and effectively used by students.

A typical classroom is already a community of practice and learning. Teachers and students are not blank slates when they encounter Computer-Supported Collaborative Learning (CSCL) systems. College students, in particular, are not novices at assuming the role of student; they are skilled students with a lot of experience. They already have social roles, norms and conventions that effect social interaction and communication.

A major force affecting classroom communication and social interaction is authority, which gives certain people, objects, representations or ideas the power to affect thought and behavior. CSCL systems require students and teachers to change how they understand and assign authority. Students need to assume more authority, assign authority to their peers, and to value their own thoughts and ideas. However, this is not an easy transition to make.

Authority is often left out of the discourse of learning. Simon (1980) argues that authority has developed such a bad reputation that people avoid examining it: "A philosopher cannot discuss it without exposing himself to suspicion and malice. Yet authority is present in all phases of social life" (p. 13). Authority, he argues, is seen as unjust, unnatural, false and anti-democratic. But for a community to have common goals, communication and shared knowledge, authority is essential: A community needs "authority to unify its actions" (p. 50).

Appears in the 2002 *Computer Support for Collaborative Learning Conference Proceedings,* Lawrence Erlbaum, pp. 481-489.

Authority is defined for this paper as the power to influence thought, opinion or behavior. People in authoritative positions, such as teachers in the classroom, can give students authority. Students can also gain some authority by citing authoritative sources, such as textbooks or lecture notes. Authority is what a person, idea or object needs to gain influence or power to change the thoughts of students.

The authority of participants in CSCL and of the representations they use for learning can have a negative effect on collaborative learning. A representation takes on the authority of its creator and the conventions they use. We found that for undergraduate students, whether or not a certain type of representation is used to build understanding has more to do with the authority of the representation, rather than its explanatory power.

In one study described in this paper, the students' perception of authoritative knowledge led them to difficulties when they engaged in collaborative learning. The students tried to use one representation presented by their instructor to answer all questions posed to them, regardless of whether or not it was an appropriate representation to use. They converged on a shared understanding based on one representation given by their instructor. Convergence early in the learning process is a hazard that is apparently difficult to avoid.

We also describe another study of students using the prototype of a system for supporting web-based collaboration called CAROUSEL (Collaborative Algorithm Representations Of Undergraduates for Self-Enhanced Learning). Students shared their own representations of algorithms anonymously, and viewed and evaluated each other's representations. In this study we found that the type and style of the representations converged over the course of five weeks. At the beginning of the study, many different types of representations were created, including ones with 3-D animation, sound and text stories. By the end of the study, though, most of the representations were explanatory graphics and text representations, without metaphors and analogy. These were similar to the representations one would find in the lectures students attended and in their textbook.

Feltovich and his colleagues argue that multiple representations will help students learn difficult concepts by making them view the concepts from different perspectives (Feltovich, Spiro, Coulson, & Feltovich, 1996). They argue that working in groups will necessarily bring multiple perspectives. However, our studies suggest instead that convergence is a likely occurrence, even when teachers or classroom conventions are not exerting authority during a learning activity. Students judged representations often on their ability to fit with cultural and classroom norms, rather than their ability to explain, communicate or enlighten.

This paper suggests methods to avoid early convergence and to encourage divergence with CSCL systems. Instead of ignoring the issue of authority, CSCL system developers are encouraged to acknowledge it and find productive ways to grant authority to students in learning contexts, taking into consideration their understanding and uses of classroom authority. Also, it is important to either adapt the system to the current social activities and arrangements in the classroom or to make it explicit how the social arrangement will change and have participants accept and take ownership of that change. The authority of a representation needs to be considered as a significant dimension in its power and in its ability to contribute to learning.

OBSERVING STUDENTS WHILE LEARNING ALGORITHMS

To discover what methods, representations, resources and strategies students use to learn about algorithms, a qualitative study was conducted with an introductory algorithm analysis class. Students were observed learning Quick Sort, a sophisticated sorting algorithm, and were then interviewed about the strategies they normally use to learn algorithms.

Quick Sort sorts a list of numbers as follows. If the list to be sorted contains zero or one number, the list is already sorted. Otherwise, the algorithm selects a number from the list; this number is called the pivot. Then, the list is partitioned into two lists such that one list contains all the numbers less than or equal to the pivot and the other list contains all the numbers greater than the pivot. Note that all the numbers in the former list are now smaller than the ones in the latter list. Then Quick Sort is recursively used to sort those two lists. Thus, the algorithm sorts a list of numbers by recursively partitioning it until lists of size one or zero are reached. Together with the previous observation, it follows that the whole list gets sorted.

Sixteen students enrolled in an introductory algorithm analysis class were observed and videotaped learning the Quick Sort algorithm and then answering a set of problem-solving questions, in six groups of two to three students each. Subsequently they were interviewed, either in groups or individually. The students in the study were told to bring their textbook and any other resources they generally use for leaning algorithms to the study. Once they arrived, they were shown a videotaped lecture on the topic. The videotaped lecture resembled the lectures they normally attended, i.e. it was presented by their instructor, who used only a white board and markers, his usual method of presenting the material. The students were given lecture notes, something that is normally given to them in their class, which summarized the material and presented the pseudocode of Quick Sort (i.e. a description of the algorithm that is not tied to a particular programming language). After viewing the videotape, the students discussed the lecture and worked together to answer questions given to them about the algorithm.

Studying student practices in this way has some ecological validity, since the students reported in the interviews that their most common method for studying was to study in groups and work on problems related to the topic. They regularly gathered together to study, complete homework problems and even program together. They reported that the way that they studied in groups for the study was similar to their normal practices, except in the study they were not familiar with all the members of their group. Students were grouped together randomly for the study, and the students in the study were quite different from each other. The students' sex, race, work experience, previous schooling, nationality and age varied considerably. Thus the study unintentionally grouped students together who had never met and did not normally study together. Despite this, and despite the fact that the students were not explicitly asked to collaborate with other members of their groups during the study, all students chose to work together and learn from each other, and all but one of the students reported enjoying working as a group in this experiment.

Problems with student learning of algorithms in this study could often be linked to the students' perception of classroom authority and what is considered authoritative knowledge. When the students were asked to answer questions that required using some other source than their lecture notes, they failed to answer the question correctly. They usually constructed an explanation based on their understanding of the lecture, rather than investigate the question using the textbook they had brought with them. The few students who did look at the textbook to answer these questions were not able to convince their peers to do the same or to consider their answers, even when their answers were correct. These other resources and the answers or understanding derived from them were not considered authoritative for most students in the groups.

The students in this study chose to consider a single representation presented by the instructor over all the other representations presented or available to them for understanding the algorithm. This graphical representation became central to their understanding of the algorithm, and they acted as if they would be able to understand everything about the algorithm by trying to reason using this one representation. The representation had acquired the authority of its presenter, their instructor, and the students believed by working out other examples using this single representation, they would be able to learn all they would need to know about this algorithm.

Classroom authority

CSCL researchers seem to give more authority to students in the classroom with their systems. They would have the instructor act more as a facilitator than an authority figure and give more agency and learning responsibility to the students (Koschmann, 1996). However, in many classrooms, the role of an instructor is to exert and control authority. Most instructors, including university instructors, are responsible for explaining new concepts and providing a learning environment, but as McCroskey and Richmond argue, exerting and using power effectively is also an important part of a teacher's job (1983). Instructors, though, usually do not acquire authority for its own sake, but instead they use power to gain authority to influence student-learning practices. Classroom management practices, such as giving assignments, motivating students to participate in learning activities, and helping students become better members of the class, rely on the teacher having authority (Richmond & Roach, 1992).

However, power and authority have to be granted, and in the classroom, the students hold the ability to grant authority. Although the institutional status of an instructor gives some initial authority, students must consent and comply with the teacher's plans for her to have authority. To say, as Jackson does (1976), that students have no agency or power in the classroom just because the students have to be there, ignores students' ability to resist. Richmond and Roach give the example of substitute teachers who are unable to gain authority and in extreme cases are driven crying from classrooms, to show how students can resist authority (1992).

College students primarily comply with authority, though, and the resistance that students create tends to be passive and partial, such as complying reluctantly, i.e. doing the minimum needed to pass the class, deceiving the instructor, and cheating. Student resistance can also be constructive, such as asking clarifying questions during class, assisting other students in learning the material, studying together, and providing constructive feedback. Constructive resistance to authority can help students become more active learners (Burroughs, Kearney, & Plax, 1989).

As noted earlier, most of the students in the study reported regularly participating in resisting authority, through collaborating on assignments, studying together and working together to understand the content. Constructive collaborative learning was already a natural, normal learning process for them.

Classroom contract

Students in the study appeared to believe in an implicit contract between the teacher and the class. This contract had been violated when in our study the students were asked questions that required them to do their own investigating rather than relying on the instructor's lecture. The students reported believing that what should and does happen in the classroom is that the teacher will tell them what to learn and how to learn it. They believed that if they were expected to know anything not explicitly said by the instructor, they should be able to be derive that knowledge by working out example problems given in class. In other words, if the student fails to learn something the teacher expects them to know, it's not that the teacher did not address the topic, only that they were not attentive enough to the details of what was said and what can be derived from what was given. Everything that needed to be learned should be in the lectures.

The students appeared to believe in a contract like the one described by Sizer in high schools. He describes students and teachers making a contract to reduce discomfort. The students are seen as trying to reduce stress and work, and teachers are seen as wanting to keep up an appearance of control. To come to an agreement, teachers don't demand much work and students behave (Sizer, 1984).

The attitude of the students in the study toward learning algorithms seemed to be that learning is something done in order to pass a test. They reported that they did not believe that the information learned in their classes would be applied outside of the classroom. They did not seem to engage in self-directed learning to learn about algorithms.

The students said during their interviews that they found the lecture notes provided by the teacher easier to understand and to use to study than their textbooks. They said generally they found the textbooks in computer science courses difficult to use. The lecture notes handed out by the instructor of this algorithms course gave more of an overview of the concepts covered in each lecture, provided less of the reasoning behind using a particular algorithm to solve a problem, used fewer mathematical symbols than the textbook, and gave less background information and comparisons with other algorithms. The lecture notes summarized the main concepts in the textbook, highlighting the key points from the lecture that the professor expected the students to know.

Most students reported not using the textbook until the night before an exam to reinforce the material in their lecture notes. The lecture notes were considered their most important learning resource, since the notes more honestly reflected the intentions of the instructor. The students did not believe they would need to use the textbook for learning. The implicit contract they believed they had with the teacher involved the teacher making it easier for them to learn the expected material and the students then would comply with that contract.

For similar reasons, students in the study relied on one graphical representation presented by the instructor in the videotaped lecture to answer all the questions about the Quick Sort algorithm. The students seemed to believe the contract would not be violated and that the representation could be used to answer all the questions posed to them. However, the questions posed to them could be correctly answered only by applying representations and concepts other than those explicitly covered in the videotaped lecture.

Learning problems arising from their adherence to the classroom contract

Most of the problems that students had in learning the Quick Sort algorithm in the study had to do with their reliance on an authoritative representation. They almost exclusively used and misinterpreted a single representation of the algorithm presented in the video (a recursion tree diagram, a type of diagram commonly used by experts to explain recursive algorithms). Groupthink (Janis, 1967) was a problem for all of the groups. Often the students would convince each other that explanations based on a faulty understanding of the algorithm were correct. They convinced each other that they did not need to use the textbook to answer the questions, and even decided not to accept correct answers that some group members derived from other sources such as the textbook.

The main learning strategy employed by students was to imitate an example presented to them by the professor on the videotape. The students seemed to believe that if they attacked problems in a way similar to how the instructor worked out the example in the lecture, drawing diagrams similar to the one they were given during the lecture, they would be able to correctly answer the questions. They did this, even though not all the information they needed to answer the questions was in that representation of the algorithm.

Although the recursion tree diagram is a representation often employed by experts, this diagram interfered with the students' understanding of the algorithm. The problem of incomplete understanding of the algorithm occurred because the students did not understand the *limitations* of this graphical representation. They believed it captured everything they needed to know about the algorithm, rather than just showing a partial and high-level view of the algorithm's execution. The instructor explicitly said while presenting this representation that all he was showing using this representation was a part of the algorithm, the recursive calls. Despite this, and despite the lecture and the pseudocode given to the students referring to other equally critical aspects of the algorithm (such as the partitioning step), students seemed to think that the recursion tree diagram was all they would need for learning and understanding the algorithm and answering the questions correctly.

All the students observed realized when they encountered questions about steps not explicit in the recursion tree diagram, such as the partitioning step or pointer manipulation, that their understanding of the algorithm was not complete. But instead of reaching out to other representations and explanations available to them, they struggled to invent answers to such questions. The information to answer these questions was available to them in their textbook. However, even when students were observed using the textbook, it was clear that they were frustrated and unable to integrate their knowledge from the lecture, their mental representation of the algorithm, and the description provided in the lecture with the descriptive material in the textbook.

All the students originally believed that if they worked out enough examples, drawing diagrams similar to the ones they were given during the lecture, and thought hard about the diagrams, they would be able to answer the questions. Instead of seeking the answers from other sources they tried to *derive plausible explanations* from one representation that did not contain any information that would be helpful with those questions.

Students converged on one representation and understanding of the algorithm. The instructor did use another representation during the lecture, the pseudocode. However, he spent more time explaining the algorithm using a recursion tree diagram, and thus, lent the graphic representation more authority. The selection of a representation to use to understand the algorithm had to do with the authority assigned to it, rather than its explanatory power. The learning problems found by this study are consistent with Milgram's studies on student obedience to authority (Milgram, 1963, 1965). Too much conformity can lead to Groupthink, during which a group converges on a poor decision or solution (Janis, 1967).

When Gifford and Enyedy studied how students used the Probability Inquiry Environment (PIE) (Vahey, Enyedy, & Gifford, 1999), they found that when students tried to reach a consensus on probability questions, they chose similar poor solutions (Gifford & Enyedy, 1999). The students, they say, often agreed on the first solution that they could agree on, rather than continue to consider and explore alternatives.

Students simplify things that are more complicated. They have a reductive bias, in which "only one of, or a small number of, the legitimate and useful ways a topic or phenomenon could be construed are recognized or considered, thus limiting understanding" (Feltovich et al., 1996). The students adopted a single representation and understanding and applied that representation, even when it was not appropriate to do so. "Students seem to prefer single models in learning and understanding. These restricted perspectives are then overextended in ways our research has shown to be detrimental to learning" (Feltovich et al., 1996).

CREATING, SHARING AND EVALUATING MULTIPLE REPRESENTATIONS

We propose that students should engage in an active process of representation *creation, sharing* and *collective evaluation* to combat this tendency of overextending authoritative representations. Students are more likely to accept representations as being incomplete and partial when created by their peers, rather than by an authority figure. Thus they may be better able to understand that different aspects of the algorithm need to be understood, and that different representations de-emphasize, as well as highlight, different aspects. By sharing their representations, they will be better able to compare their understanding with others.

We built a prototype system called CAROUSEL to help students create, share and evaluate their representations of algorithms. It was used in a pilot study with 12 students in a beginning data structures course. The system collected and displayed student-created representations and collected the ratings students gave to the other students' representations for certain characteristics of these representations, such as ratings for usefulness, understandability, familiarity, salience, contiguity, and pleasure.

The students created representations for three algorithms: the algorithm for generating Fibonacci numbers, the Selection Sort algorithm and the Merge Sort algorithm. After the students evaluated the representations, the average ratings on each characteristic for each representation were posted to the CAROUSEL web site along with the names of the authors of those representations.

At the beginning of the study, students chose to work with a wide variety of media, including text, graphics, sound and animation, based on their personal preferences. However, over the course of the study, the students converged on a simple style, one incorporating primarily simple graphics and text. For the first algorithm approximately 64% of the representations were text only, 9% were text and graphics, 9% included animation and sound, and 18% employed more complex media. For the second algorithm, the number of text-only representations decreased (37%), those with graphics increased (50%), and the use of animation and complex media decreased (18%). By the last algorithm, only text representations (57%) and representations with graphics (43%) were used.

Students were tested after they created representations to measure their knowledge of the algorithm. Initial results from the pilot study suggest that the constructive activities do help learning. For two of the three algorithms that were used in the pilot study, there was a significant positive correlation between creating and sharing a representation and test scores ($r=.635$, $p=.07$; $r=.663$, $p=.05$), compared to students who did not engage in these activities.

Missing contract/Missing authority

However, students find it difficult to communicate with each other when the authority of an instructor is missing. Stubbs (1983) studied how teachers control communication in the classroom. Teachers often control what is discussed, how much of it is discussed and how it is discussed. The teacher controls not only how much time they discuss something, but also how much time others have to respond. Also, for a student's solution to be considered correct, the student has to recognize an instructor's authority and has to adopt her methods of communication about the topic (Stubbs, 1983).

Similarly, students using Guzdial's CoWeb, a CSCL system that has students build knowledge collaboratively on the web, relies on the instructor's involvement and monitoring of student activity with the system. "The teacher's attitude and involvement is critical – since so many students were in the CoWeb mostly to hear from the teacher, a missing teacher might lead to less student involvement" (Guzdial et al., 1999). Even though students' attitude toward the classroom contract has changed with the use of CoWebs in the classroom and students no longer see the teacher as the main source of information, they are still placing authority in the teacher through valuing the teacher's opinions and teacher-approved discourse produced by students.

Even in classrooms where more progressive teaching methodologies are practiced, teachers often still maintain considerable control over what the students are doing. Edwards and Mercer studied classrooms where small-group learning was being used and found that although the students appeared to be working independently, the teacher was really controlling the discussion and actions of the group (Edwards & Mercer, 1992).

Studies of undergraduate students at Georgia Institute of Technology enrolled in classes where collaboration was part of classroom activities suggest that the students dislike and resist efforts to make them engage in collaborative learning (Hmelo, Guzdial, & Turns, 1998; Newstetter & Hmelo, 1996). One wonders whether these students were resisting the teacher's authority or the teacher's lack of adhering to their classroom contract. Jones' study of two New Zealand classrooms found that students exerted control over the teacher's curriculum and methods. The students in her study resisted when the teacher tried to have the students learn something other than facts, and did something other than lecture and testing on notes (Jones, 1989). Similarly, Oyler found that students shape teachers' actions in the classroom and can exert authority. The teacher in the study wanted the students to share some authority in the classroom, but she was not happy about how they exerted it (Oyler, 1996).

Students building authority based on convention

Our pilot study with CAROUSEL showed that when authority in terms of a person or instructor is missing, students build authority using other means. In the case of the pilot study, the students found authority in the representational styles used in the textbook and lectures. Over the course of the study, students moved from individualistic, metaphor and media-rich representations at the beginning of the study to an explanatory, example-based style with graphics and text. They converged on a style that mimicked what they saw in the textbook and lectures. At the beginning, one saw metaphoric stories and complex three-dimensional graphics, by the end of the study, one saw texts that primarily walked a student through an example and explained the steps of an algorithm clearly.

One of the researchers rated all the representations in the study on a scale of 1 to 5 with 1 being a rating for representations that are least like a textbook or classroom explanation and 5 being a rating for representations that are most like a textbook or classroom explanation. These ratings increased over time with each new algorithm: the first algorithm had an average rating of 3.4; the second had 3.9; and the third had 4.7.

Furthermore, the average of all the ratings the students gave each representation is significantly positively related to the rating of how similar that representation is to a textbook or classroom explanation ($F(1, 24)=3.9$, $p=.06$). Multiple linear regression analysis techniques were used to explore how the ratings of the representations' similarity to textbook or classroom explanations were related to the student ratings of different characteristics. The similarity rating's relations to students' ratings of usefulness, salience and contiguity are positive and significant ($F(1,24)=6.5$, 6.0, and 10.6 respectively, $p<.05$). In other words, how similar a representation was to a textbook or classroom explanation positively influenced student ratings for how useful that representation was for their understanding of the algorithm; how well that representation pointed out the salient features of the algorithm; and how well it was contiguous with (built upon) the other representations for that algorithm. For understandability and familiarity, the effect was also positive, but not significant. Interestingly, pleasure was the only student rating that was negatively affected by a representation's similarity to a textbook or classroom explanation, but the effect was not significant. Summarizing, how similar a representation was to a textbook or classroom explanation influenced what kind of rating a student gave to that representation, and usually, the more a representation was similar to what they saw in their textbook or classroom, the higher the rating was.

A follow-up interview with one of the participants in this study was consistent with this theory. During the interview, the student was asked to talk about each representation. He frequently talked about them in terms of doing things the "class way" or something being "teacher-like". He was then asked to rate the representations according to how "normal" they were. He responded, "By normal, do you mean most like what we see in class?" He was instructed to define it the way he thought was most appropriate, and he said that he thought "most class-like" was the most appropriate way to define normal. According to him, the best representations had the pseudocode, a picture or visualization of the algorithm and a plain-text explanation using an example. He explained, "It is really the best combo. Teachers do that."

However, at the beginning of the study, most students were turning in representations that did not look anything like the style he described. He was asked if he remembered what he thought when he was given the first assignment for the study. He replied, "Yeah. We were upset. You have to see when you're that young in college trying to do your best... When someone just tells you to get creative … it is hard for me to get like that." The students felt a lot of anxiety about turning in the first set of representations, and they complained about not being given enough direction the day that they were due. The authority was missing, leaving them to create their own idea of what would be a "good" representation. They then seemed to be converging over time on the conventions and styles used in the classroom or found in the textbook.

When this particular student was asked about how he felt about the other students rating his work, he reported that he looked at them and competed with his classmates to get the highest rating. However, he was upset that the feedback he got was from his peers. "I don't trust my classmates as much as I trust professors," he said. The feedback did not carry enough authority for him. When asked how to improve the study, he thought the instructor rather than the other students in the class should do the rating.

RECOMMENDATIONS

In this section we present a set of recommendations for CSCL systems to effectively exploit the effects of authority. We have revised CAROUSEL in a manner consistent with these recommendations and are currently fielding and evaluating it with a similar, but larger scale study (60 participants, nine algorithms, and a duration of 12 weeks) in a junior level algorithms class during Fall 2001.

Allow students to both work alone and together

Having students participate in both dialog and monologue is critical for effective collaborative learning (Hoadley & Enyedy, 1999). Monologue does not depend on the context, social cue and interaction to communicate and interact with ideas, whereas dialogue has distributed control of the conversation among participants and involves interaction, common construction and sharing of ideas. Psychologists have argued that students should produce monologues of their own understanding (Chi, de Leeuw, Chiu, & LaVancher, 1994). However, making one's initial understanding available for further dialog is also critical for active learning.

Certain CSCL systems seek to balance student monologue and dialogue. The CoWeb system has students display individual work on web pages and then allows others to edit that work to create a dialogue about their understanding

(Guzdial & Kehoe, 1998). CSILE (Computer-Supported Intentional Learning) supports students in collaborative knowledge building activities by creating a shared database that contains student representations of their knowledge. Students can author their own ideas and record them in the database, but their knowledge is linked to the knowledge already in the database, the social knowledge repository. The system promotes both individual reflection and group interaction with the knowledge base (Scardamalia & Bereiter, 1991). Hoadley and Enyedy (1999) used two different complimentary tools, SpeakEasy and SenseMaker, to support monologue and dialogue: SpeakEasy helps students have structured discussions, and SenseMaker helps students create an overview and integrate ideas.

Encourage divergence

Students need to be explicitly encouraged to diverge from cultural norms and disagree with each other, especially at the early learning stages. CSCL systems and teachers need to challenge students who believe that one representation can and does represent all aspects of a concept. Instead, students need to be encouraged to look for differences between representations and see the aspects that are obscured and hidden by any particular representation. Allowing students to work alone initially will likely encourage more divergence, but it alone will not prevent them from picking one representation among the many and using that one to the exclusion of others during collaborative learning. Integration and consideration of differences should therefore be explicitly encouraged.

Lessen effects of identity

Another important recommendation is to lessen the effects of identity within the system. Certain students in a class have more authority than others. As students reported in their interviews, students start college classes knowing which of their peers are more likely to receive good grades and understand the material. The representations or arguments of these students may carry more weight than those of others, encouraging convergence and the silencing of differences. So it is important in the early stages of a collaborative learning activity that student authors remain anonymous to lessen the effects of identity on convergence and engagement.

Rewrite the classroom contract

For collaborative learning to be successful in the classroom, the classroom contract has to be explicitly rewritten. Authority should be reassigned, based on input and agreement of both the teacher and students. Power and control are negotiated through interaction. Power does not reside in either the teacher or students, but instead is created between them. “A more dialectical and less functionalist perspective considers power and control as dynamic processes that are constructed and negotiated between teacher and students. … It is through teacher-student communication that power is developed, attributed and maintained” (Staton, 1992, p. 173).

Authority cannot be successfully assigned by a computer system or even a social system such as the school system without the agreement of the participants as discussed earlier. For collaborative learning to be successful, the participants must make explicit the new terms and arrangement of authority.

For students and teachers to agree to a collaborative learning activity, it must be clear to both parties what the intended roles of the participants will be and what benefits one will receive from the additional responsibility and authority. One student who had used CAROUSEL in the pilot study said he felt that it needed to be clearer how the study was related to his class and how he was benefiting from it. “Tie the representation assignment with the class. … It should have been more tied with our assignments every week,” he suggested.

Gifford and Enyedy (1999) argue that CSCL environments should be designed by looking at the activities they are supposed to support. They argue that many CSCL systems do not fit with nor change the basic activities of the classroom, and therefore have little effect on the learning of students. They propose that CSCL systems should focus on supporting activities where learners and the teacher plan and participate in learning activities. CSCL systems have to be integrated into the social activities in the classroom. Successful classroom practices and authority are negotiated, rather than dictated by the teacher. Similarly, the authority given to a CSCL system has to be negotiated. The best learning environment is one that can flexibly adapt to the learning activities already negotiated in the classroom.

CONCLUSION

Authority was instrumental in how college students used, created or evaluated representations in the two studies described in this paper. Students converged on an authoritative representation or representational style and ignored the limitations of that representation or style and other available representations. The students’ understanding of authority in the classroom discouraged the critical analysis and questioning of representations. Instead of evaluating a representation by looking at its content and how well that is expressed, judgments by students were based on how much time an instructor invested into a representation or how well a representation fit with the style normally used by textbooks and in lectures. This discouraged students expressing original viewpoints of the concept, and instead resulted in students looking at the same aspects of the concept in the same way.

Some argue that collaboration necessarily leads to a diversity of ideas. “It is more likely in a group that the limits of single interpretations or representations will be counteracted by alternative interpretations” (Feltovich et al., 1996, p. 36). However, how authority is assigned, recognized and resisted greatly affects whether this will happen. Instead of alternative interpretations arising in a collaborative learning setting, students may work to reinforce biases, to silence those with differing opinions and to reinforce a single view of looking at the concept. The students in our studies might have been better off if they were working alone rather than collaboratively.

Design of CSCL systems needs to consider how to manage and distribute authority. By changing the perception and assignment of authority, such systems must encourage students to diverge before converging, and facilitate critical analyses of different viewpoints and representations. This can be accomplished by explicitly changing the classroom contract, and having students do independent thinking as well as engaging in dialogic activities where anonymity of authorship is preserved at least initially.

ACKNOWLEDGMENTS

We thank Sadhana Puntambekar, Roland Hübscher and anonymous referees for their helpful comments and suggestions. This research is supported by the National Science Foundation under contract CDA-9616513.

REFERENCES

Burroughs, N. F., Kearney, P., & Plax, T. G. (1989). Compliance-resistance in the college classroom. *Communication Education,* **38**, 214-229.

Chi, M. T. H., de Leeuw, N., Chiu, M.-H., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science,* **18**, 3, 439-477.

Edwards, D., & Mercer, N. (1992). *Common Knowledge: The Development of Understanding in the Classroom*. Routledge, New York, NY.

Feltovich, P. J., Spiro, R. J., Coulson, R. L., & Feltovich, J. (1996). Collaboration within and among minds: Mastering complexity, individually and in groups. In T. Koschmann (Ed.), *CSCL: Theory and Practice of an Emerging Paradigm* (pp. 25-44). Lawrence Erlbaum Associates, Mahwah, NJ.

Gifford, B. R., & Enyedy, N. D. (1999, Dec. 12-15). Activity centered design: Towards a theoretical framework for CSCL. Paper presented at the Computer Support for Collaborative Learning Conference, Stanford University, Palo Alto, CA.

Guzdial, M., & Kehoe, C. (1998). Apprenticeship-based learning environments: A principled approach to providing software-realized scaffolding through hypermedia. *Journal of Interactive Learning Research,* **9**, 3/4, 289-336.

Guzdial, M., Realff, M., Ludovice, P., Morley, T., Kerce, C., Lyons, E., & Sukel, K. (1999, Dec. 12-15). Using a CSCL-driven shift in agency to undertake educational reform. Paper presented at the Computer Support for Collaborative Learning Conference, Stanford University, Palo Alto, CA.

Hmelo, C. E., Guzdial, M., & Turns, J. (1998). Computer-support for collaborative learning: Learning to Support Student Engagement. *Journal of Interactive Learning Research,* **9**, 2, 107-130.

Hoadley, C. M., & Enyedy, N. (1999, Dec. 12-15). Between information and communication: middle spaces in computer media for learning. Paper presented at the Computer Support for Collaborative Learning Conference, Stanford University, Palo Alto, CA.

Jackson, P. (1976). *Life in Classrooms*. University of Chicago Press, Chicago, IL.

Janis, I. (1967). *Victims of Groupthink: A Psychological Study of Foreign Decisions and Fiascoes*. Houghton Mifflin, Boston, MA.

Jones, A. (1989). The culture production of classroom practice. *British Journal of Sociology,* **10**, 19-31.

Koschmann, T. (1996). Paradigm shifts and instructional technology: An introduction. In T. Koschmann (Ed.), *CSCL: Theory and Practice of an Emerging Paradigm* (pp. 1-24). Lawrence Erlbaum Associates, Mahwah, NJ.

McCroskey, J. C., & Richmond, V. P. (1983). Power in the classroom I: Teacher and student perceptions. *Communication Education,* **32**, 175-184.

Milgram, S. (1963). Behavioral study of obedience. *Journal of Abnormal and Social Psychology,* **67**, 371-378.

Milgram, S. (1965). Some conditions of obedience and disobedience to authority. *Human Relations,* **18**, 57-76.

Newstetter, W. C., & Hmelo, C. E. (1996). Distributing cognition or how they don't: An investigation of student collaborative learning. In *Proceedings of the International Conference of the Learning Sciences*, AACE, Charlottesville, VA, 462-467.

Oyler, C. (1996). *Making Room for Students: Sharing Teacher Authority in Room 106*. Teachers College Press, New York, NY.

Richmond, V. P., & Roach, K. D. (1992). Power in the classroom: Seminal studies. In V. P. Richmond & J. C. McCroskey (Eds.), *Power in the Classroom: Communication, Control and Concern* (pp. 47-66). Lawrence Erlbaum Associates, Hillsdale, NJ.

Scardamalia, M., & Bereiter, C. (1991). Higher levels of agency for children in knowledge building: A challenge for the design of new knowledge media. *Journal of the Learning Sciences,* **1**, 1, 37-68.

Simon, Y. R. (1980). *A General Theory of Authority*. University of Notre Dame Press, Notre Dame, IN.

Sizer, T. (1984). *Horace's compromise: The Dilemma of the American High School*. Houghton Mifflin, Boston, MA.

Staton, A. Q. (1992). Teacher and student concern and classroom power and control. In V. P. Richmond & J. C. McCroskey (Eds.), *Power in the Classroom: Communication, Control, and Concern* (pp. 159-176). Lawrence Erlbaum Associates, Hillsdale, NJ.

Stubbs, M. (1983). *Language, Schools and Classrooms* (2nd ed.). Methuen, London.

Vahey, P., Enyedy, N., & Gifford, B. R. (1999). The Probability Inquiry Environment: A collaborative, inquiry-based simulation environment. Paper presented at the Thirty Second Annual Hawaii International Conference on Systems Sciences.