The complex jigsaw as an enhancer of collaborative knowledge building in undergraduate introductory cognitive science courses

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ABSTRACT
Teaching cognitive science to undergraduates is a challenging task since the field is highly interdisciplinary. In this paper, we first report on structured coursework developed to cover a single topic in cognitive science to show how deliberate relation-making activity, supported by an enhanced note-sharing system called ReCoNote, can help students start their own knowledge construction. We then introduce a more complex curriculum designed to present a broader view of the field to the students by further utilizing deliberate relation-making with the same system. We rely on the "jigsaw" method to support this endeavor. We have expanded this into a complex college-level work-oriented collaborative situation where students move in and out of hierarchically structured "expert" and "study" groups to enable them to perceive the width and complexity of the interdisciplinary nature of cognitive science. In the latter part of this paper, we offer a concrete description of how this complex jigsaw is structured, using some beginning analyses of the students' activities on ReCoNote in this complex jigsaw classroom.

Keywords: complex jigsaw, collaborative knowledge building, teaching cognitive science

INTRODUCTION

To encourage students in the undergraduate introductory courses of cognitive science to deliberately form relations among learning material pieces is beneficial for their knowledge building. We have been developing and testing an enhanced note-sharing system called ReCoNote, or Reflective Collaboration Note (Miyake & Masukawa, 2000; Masukawa, 1999) to support this activity. The overall result presently indicates that support of relation-making among learning materials by the system can and should be strengthened by designing a specific course structure.

Teaching cognitive science to undergraduates is a challenging task since the field is highly interdisciplinary and requires the introduction of many new concepts and approaches in a relatively short period. It is desirable that the students be exposed to the diversity of approaches to human studies and their interplay from the beginning of their study. Collaborative learning situations are particularly suitable because they present the challenges that researchers in the field undertake regularly as professionals. However, this requires careful design of the coursework and methods to accomplish this have not been widely investigated.

In this paper, we first report on structured coursework developed to cover a single topic in cognitive science to show how relation-making, supported by the ReCoNote, can help students start their own knowledge construction. We will then introduce a more complex curriculum, designed to present a broader view of the field to the students by further utilizing deliberate relation-making with the same system. We expand Elliot Aronson's cooperative learning method, called the "jigsaw" classroom (Aronson & Patnoe, 1997), to support this endeavor. By building upon this method, we create a college-level work-oriented collaborative situation where students move in and out of hierarchically structured study groups to enable them to perceive the width and complexity of an interdisciplinary field of cognitive science. In the latter part of this paper, we offer a concrete description of how this complex jigsaw is structured, using some beginning analyses of the students' activities on ReCoNote in this complex jigsaw classroom.

THE COMPLEX JIGSAW

The jigsaw method was first developed to cope with cultural diversity in classrooms (Aronson & Patnoe, 1997). The method was then expanded into a more sophisticated system to turn such culturally diverse situations into learning resources (some current reports can be found at http://www.jigsaw.org/).

In an ordinary jigsaw class, students first study a piece of material in an "expert group," and then form a separate study group, or a "jigsaw" group, consisting of one member from each of several "expert" groups. This situation makes every student responsible for her own learning, and also helps the entire class understand the benefit of respecting others. This jigsaw method was first developed by Aronson and his social psychology team to "teach cooperativeness as a skill" (Aronson & Patnoe, 1997, P. 14).

As a commonly-used example, the jigsaw class for reading comprehension progresses as follows: Children are divided into groups with a small number (e.g., six) of members per group. Reading material is then divided into six sections so that every member of each group is responsible for one of the six sections. After reading the sections individually, the groups are rearranged so that the members from each group that were assigned the same section can assemble and communicate their understanding of the material, and they prepare themselves to present their understanding of their portion of the reading material. These temporary groups are called "expert groups." They are then re-arranged into the original groups, where each member contributes her/his share of the perception of the material to the other members of the original group. After the sections are all explained, the students are ready to take a comprehension test to demonstrate that they have come to understand the material as a whole. This method has been carefully tested for its effects on a diverse set of topics, including children's acceptance of their groupmates as intellectual peers, their self-esteem, and their mastery of the classroom materials. According to Aronson and his colleagues, the effects are consistently positive.

The jigsaw method can create a rich environment for intellectual collaboration and is a concept that has been used by other researchers in the field of collaborative learning (e.g., Brown, 1997). Along a similar line, we developed this into more complex and highly structured course work, wherein college students move in and out of hierarchically structured "expert" groups and "jigsaw" groups. Starting with more than simple six-piece material, we prepared learning materials in an n by m matrix of perspectives A and B. A student is assigned to a cell in the matrix and automatically becomes a representative of a particular perspective Ai on dimension A, as well as of perspective Bj on dimension B. The course work is thus structured to require her to sometimes work in one of the expert groups on perspective A, while at other times she is required to be an expert on B. We explain later in this paper how this was accomplished with a specific course topic and report on how the ReCoNote system was used. More detailed and content-oriented data will be reported at the conference.

RECONETE AND HOW IT CAN BE USED: FROM RELATION-MAKING TO SENSE-MAKING

ReCoNote has a special capability called "mutual linking," which refers to the system's feature that requires the learners to think about the relationships among the learning materials from two different perspectives. When a teacher organizes a series of classroom activities around a theme, very often the overall structure is not explicitly presented in the lecture. Interviews with students have revealed that such hidden organizations are not always perceived or explicitly understood by the students. We hypothesized that this situation could be improved by explicitly requiring the students to engage in relation-making so that they can start making sense on their own of the variety of materials they need to cover.

ReCoNote: The system

A collaborative learning support system called ReCoNote, or Reflective Collaboration Note, has been developed and put in use in college level cognitive science classes. It is a note-sharing system with a mutual-linking capability. When learners encounter two "linkable" pieces of information, they are explicitly

asked to link them together with specific comments regarding the relationship. The linked comments are stored and presented in a list whenever the attached notes are viewed. The two pieces may be the student's own note, another's note, a group's note, or class material provided by the teacher. The system's mutual linking feature requires the learners to adopt multiple perspectives on the learning materials by asking them to write link comments bi-directionally; for example, for notes A and B, first from A to B and then from B to A.

ReCoNote has two windows that show two sections of learning materials at once (Fig. 1). The materials include the student's individual notes as well as group notes and teacher-provided learning materials with announcements of classroom activities and of system support. Each note comes with a "link list," a list of comments with the author names for links that tie the information in the adjacent window to some other piece of information in the overall note system. Clicking on the comment causes the linked information to appear in the other window on the screen. All of the information can also be called up onto one of the windows by going through a menu provided at the top of each note.

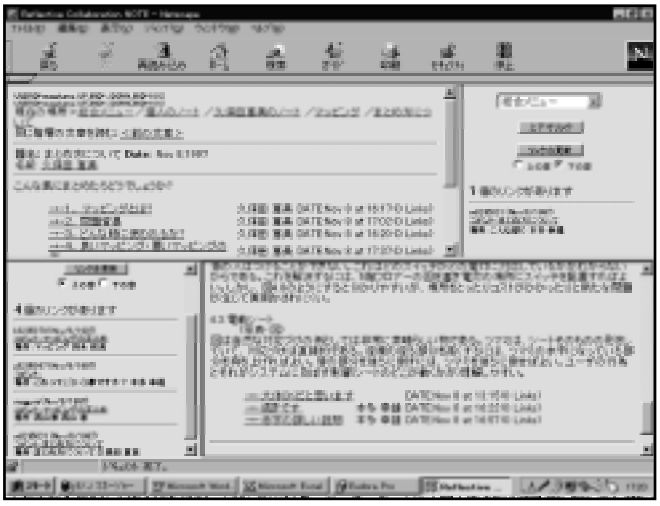


Figure1: ReCoNote windows

To write a note, the student clicks on the "make a note" button, which opens up a new window. There is a separate small window to write in the title of the note, which will appear on the menu in a list of titles. If the student wishes to create a link between the two notes he/she is currently working on (most typically this happens when a student is writing his/her own note while examining another piece of information in the other window, such as teacher-provided learning material or notes created by other students), a click on "make a new link" at the bottom opens a new window with two slots in which to write comments to explain why the two pieces of information are related. There are two slots because the system explicitly asks students to think about the directionality of the link; with notes A and B, one relation could be made from A to B, while the relationship from B to A often requires another type of specification.

Curriculum to support the use of this system

Several curricula have been developed to take advantage of ReCoNote, covering both upper and lower level undergraduate courses in cognitive science. We report here on a course on problem solving, an upper level elective course. The goal of the course is to review literature and write a summary report on human characteristics as a problem solving system. The active enrollment was 57.

There were three phases in the class; the first was the literature review phase. Students were grouped into small "expert groups" according to their interests in topics covered in classical problem-solving literature. In the first class, they answered questions on classical puzzles--what they are, how to solve them,

and how much literature is associated with each puzzle that they know. Upon answering this set of questions, they decide which puzzle they will use as their literature research topic. The students are then grouped together into 23 groups according to the topics. In our 1998 practice, the topics ranged over 11 puzzles, including the Tower of Hanoi, the Luchins' water jar, the Polson's water jar, the river crossing problem, the Wason four-card problem, the monkey and the banana problem, Baysian statistics problems, and Dunker's stomach ulcer problem. The results of these literature studies were reported onto ReCoNote, covering some variations of the original research. For example, the students were encouraged to include many different types of discourse for the Tower of Hanoi puzzle. They could include explanations of the original game, the difficulty human solvers generally encounter when solving its typical dissemination (five-disk version), the recursive structure of its general solution, its role in the development of the typical information processing model of problem solving system, like GPS in the original Simon and Newell's formulation, its variations, like the adaptive production systems, and Zhang and Norman's re-formulation of its dependence on external resources. After three weeks of preparation, each group reported what they had reviewed to the class.

The second phase was devoted to relation-making, utilizing ReCoNote's mutual linking function. During the presentation of the survey results, the "audience" students were encouraged to consider how they would relate what is being presented with what they have researched under their title. They are then required to link the important relations among the notes on the system.

The presentation and the linking took another three weeks. The groups were then asked to report to the class on the linkages they had made from among all the class notes. Prior to this, the teacher gave a short instructional lecture on how the pieces could be tied together, actually pointing to possible clustering features like the historical roles the puzzles played and the human characteristics each puzzle reveals. After the presentations of the linkages, the teacher gave another rather detailed one-hour lecture on the general view of the research field, focusing particularly on current developments, including the expansion to everyday events, collaborative types of problem solving in real-world settings, and indicated how classical research findings assist in research development.

As the summary activity in the third phase, students were required to write a report on human characteristics as a problem-solving system. This report could either be done individually or in groups. Even the individual reports require considering the overall class activity as the input—the report cannot be done properly unless the student closely examines what others have studied. The final reports were put onto ReCoNote so that the students could share the collaborative outcome of the class.

Results of the 1998 study

Forty percent of the groups (10 out of 23) turned in high quality reports under the title of "Human Characteristics as Problem Solving Systems." This rate is fairly high compared to other years, if we consider the demand for quality of the reports. We identified three types of reports among them: Integrated (3 groups), Listed (4), and Self-centered (3). In integrated reports the students covered all the materials studied by the class and attempted to provide an integrated view of a human being as a problem solver. They furnished specific characteristics uncovered by different pieces of research and then tried to depict a holistic view. Listed reports, in contrast, literally listed all the studies contributed by the class members. These were exhaustive and meticulous reports, reflecting the hard work done by the students, though less effort was made to integrate them. The self-centered reports never ventured very far from the original topic each author had begun with in the class, yet there were clear traces of their efforts to integrate the information provided by others. The difference between this and the other two types was primarily that the students who generated this type were more selective. They tended to pick out only the studies that were relevant to their topic research and structured the reports around those studies.

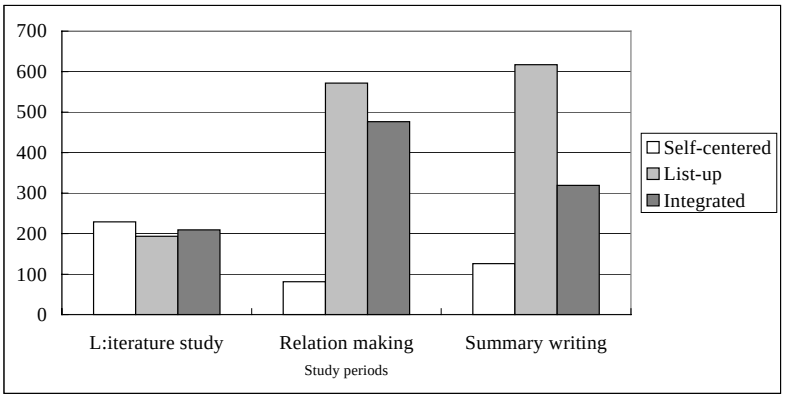


Figure 2: Number of notes visited during each study period for each report type

Figure 2 depicts the relationship between the types of final reports and the number of notes visited by the groups. The groups that produced the listed and integrated types of reports had a greater tendency to visit the created notes, particularly in the relation-finding and summary-writing phases. These activity patterns match the content and the quality of the reports, indicating that the activities ReCoNote was able to solicit had positive effects on the high performance of the students.

The activity levels observed during the classes were also higher in this class. Overall, fifty-seven students used the notes, with a total of 749 log-ins, and they all successfully finished the course. They created 310 notes in total, among which 114 were by individuals and 196 were group notes. One hundred eighty-nine links were made on them by 32 students. Table 1 shows how many notes were actually visited and by whom.

Table 1: Total number of notes visited by one's own group and other groups

own groups	others' groups	cannot tell	Total
383	6924	491	7798

As shown in Table 1, the students visited other groups' notes often. Among 23 groups, six groups visited notes written by all the groups and the other 14 groups visited notes from more than 13 groups, indicating that the created notes were actively used during the course, regardless of who made them.

All of the links (189 in total) were similarly categorized according to the types of notes they linked; i.e., whether they linked notes within one's group (own group), notes from other groups who studied the same topic (same topic/other group), or notes by other groups on different topics (different topics). Three notes remained unclassifiable. See Table 2.

As the course develops, links spread from within one's own group's notes to cover notes created by other members associated with different study topics. This suggests that the students were engaged in relation-making activities, with notes provided by other members of the class serving as building blocks to re-structure the field of the problem solving research from each student's own perspective.

Among these 189 links, 133 had comments in both directions, while 43 offered one-directional comments only. The comments were used mainly to explain the characteristics of the linked notes and their relationships. The comments were occasionally too long to fit as a "comment" to the link (i.e., longer than would fit in the given slot), in which case a whole new note was created to provide enough writing space for the commentary, and these comment-notes were then linked together. The comments were written on notes

and links, on linked notes, or on links only. This indicates that toward the latter part of the course, students started to use more notes for comments. One possible explanation for this phenomenon could simply be that they had more to express.

Table 2: Number of links made—1998 class

	Literature study	Relation finding	Summary writing	Total
Within own group	22	15	31	68
Same topic/Other group	6	6	5	17
Different topic	1	49	51	101
Unclassifiable	1	0	2	3
Total	30	70	89	189

RECONOTE ON A MORE COMPLEX DOMAIN

In the summer of 2000, ReCoNote was used in a course on the "Cognitive Science of Learning and Development." This was a three-day concentrated elective course for third and fourth year students. The ultimate goal of the class activities was to propose a new design for a traditional college course, based on their understanding of how people learn and generate knowledge. The teacher prepared twelve pieces of influential work done in cognitive science, taking three pieces from four different larger topic areas or approaches. The four areas were

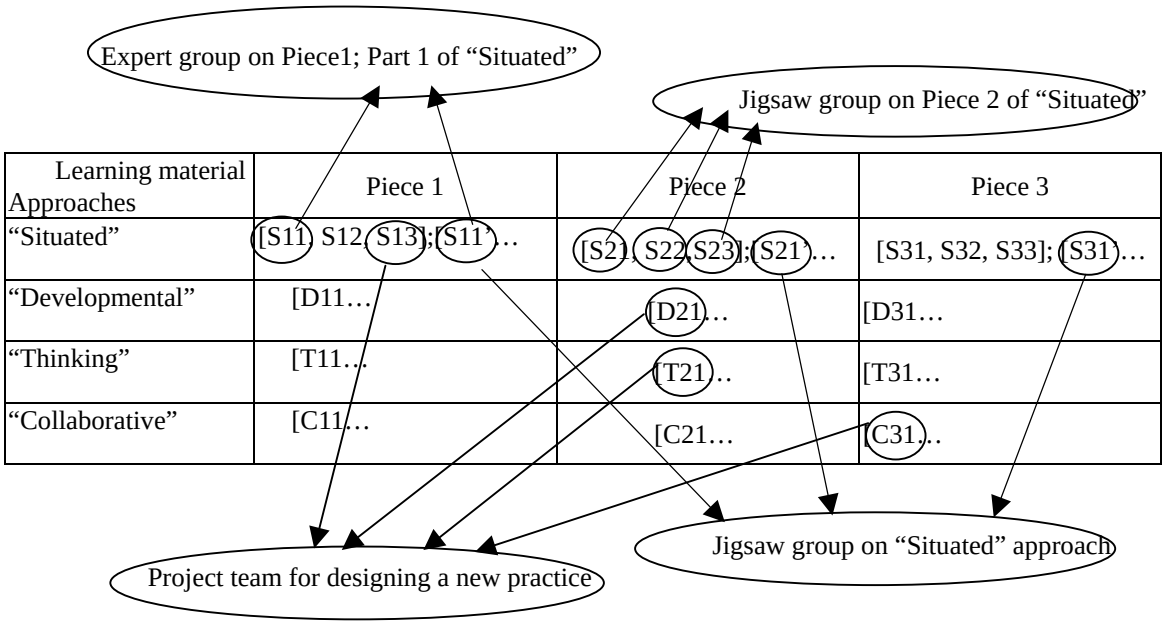
--The everyday and situated nature of knowledge use and knowledge formation ("situated view")

--The constructivist approach to developmental studies ("developmental") "

--The constructivist approach to knowledge use ("thinking and problem solving")

--The collaborative and socially distributed nature of cognition ("collaborative")

The teacher's intent for the final proposal was to have the experts from each of these four topic areas collaborate to develop a proposal. Figure 3 shows the structure of this complex jigsaw.



N.B. Symbols S11, S12, etc. denote students

Figure 3: The complex jigsaw course work design for 2000 study

The course activities

In order to develop the required proposal, each student was assigned to one of the twelve pieces of work prepared by the teacher, taking into account her/his interests as shown in her/his answers to the initial questionnaire. There were in fact more than one such groups for each piece, to accommodate the class size. The process started very much like the traditional jigsaw classroom: in the beginning, one third of the original paper of the assignment was given to each student; they read it and prepared a presentation in an expert group(e.g., S11+S11'). In the jigsaw group that followed, three students who each read different parts of the same piece gathered to co-construct the coherent whole of the original paper (e.g., S21+S22+S23). This was covered in the first day, in three 90-minute classes. The students worked on ReCoNote after the classes, writing the day's work in preparation for their presentations the next day.

On the second day, three students from each paper group separated and independently formed new jigsaw groups(e.g., S11'+S12'+S13'), which then consisted of three representatives from each of the three different material pieces under the same approach. Each member presented her summary of one of the three papers, so that at the end of this session all three were familiar with different kinds of work done under the particular approach. Note taking on ReCoNote was encouraged during this phase, using the classroom notebook computers. The class convened at this phase and had each group present their version of "what each particular approach is and how it should guide the design of new learning systems/practices." There were overlaps because multiple groups presented based on the same approach. This overlap made it clear to the entire class that there could be different understandings of the same approach, opening up the possibilities for flexible applications of the approaches to their design task. After these presentations, "collaborative work teams" were created by selecting one student from each approach (e.g., S12+D21+T21+C31) to design and propose a new learning practice. We had seventeen such groups (two had only three members), each of which was asked to work together to formulate the proposal. Answers to the initial questionnaire were taken into account for this grouping, so that students of similar minds regarding what to teach and how to teach it were grouped together.

Students spent the morning and the early part of the afternoon of the third day designing a new learning practice and preparing its presentation. Note taking on ReCoNote on classroom notebook computers was again encouraged during this phase. At the end of the course, in the latter part of the third day, all the proposals were presented to the class in a poster session. The students were split into two groups; one half presented their posters, while the other half could meet with the presenters and engage in discussions with them. The halves switched roles in two 45 minute sessions. The assigned paper reporting the proposal was due at the end of the course in three weeks, with refinements that should reflect the questions and comments collected during the poster presentations.

Sixty-six students created three hundred and thirteen notes during the three-day course, and an additional ninety-eight notes until the submission deadline of the final reports. The notes were visited 8722 times during the course, with an additional 5207 visits during the final report-making period. The notes were linked 106 times by 39 members. Among those links, 51 had comments for both ways, 41 had one-directional comments only. The notes were actively used overall, possibly because the course activities, such as presenting to the whole class, required such use. The notes were actively used even after the course, suggesting that the students took advantage of being able to revisit them while working on their final reports.

Results of the 2000 study

The quality of the final reports and the log data of ReCoNote use are currently being analyzed to examine what kinds of activities were related in what ways to the better performance in this kind of collaborative class. The table below shows some preliminary results regarding where the links were made

among the notes and whether they were links between a student's own notes, between one student's note to another's, or between/among others' notes, according to the phase (which day of the course). There was a slight increase in the number of links made among others' notes, indicating the move from seeing some coherent structure among a student's own notes to constructing some new structure by relating to notes not directly belonging to their own work. This is similar to the observation made in the above-reported class.

Table 3: Number of links made—2000 class

	Day 1	Day 2	Day3+	Total
One's own notes	0	6	5	11
Own with Other's notes	0	33	17	50
Among others' notes	0	14	19	33
Not clear	1	7	4	12
Total	1	60	45	106

FUTURE WORK

We are currently developing similar course curricula to investigate how broad an area this kind of complex jigsaw structure can cover. Modern science requires collaborative team work, yielding more multidisciplinary results. Students in not only cognitive science but also in many other disciplines will soon need to start learning to cover more diverse topics. More research into collaborative learning in structurally collaborative and thus interdisciplinary and more complex research fields would certainly contribute to making this learning situation less difficult.

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