Supporting Learning Cognitive Science Wisely through Collaborative Reflection

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Abstract: We have been developing and testing a curriculum to teach cognitive science to undergraduate students at college [1][2][3]. The curriculum emphasizes hands-on activities and collaborative reflection, and encourages each student to construct basic knowledge with technological support. While the curriculum design takes advantage of what is known in cognitive science on how people learn, testing out the curriculum in real classrooms provides us with data we can analyze to strengthen our understanding of human learning. The curriculum is designed to gradually secure the basic knowledge base of the science, as well as collaborative scientific method with which the students are able to transfer what they learn in class to real-world settings. In this report we explain our pedagogy as well as the general framework of the curriculum, with two illustrative cases: one is the case where the students learned basic constructs of the semantic net representation of human memory, and the other is a series of classes where the students developed their own knowledge-base, in a sophisticated jigsaw fashion. We will conclude this presentation with some future directions of our research.

Key words: Collaborative reflection, Undergraduate cognitive science, Note-sharing system, The jigsaw method

Learning Cognitive Science at College

Knowledge of cognitive science has implications on everyday life, how to solve problems wisely by taking into account what we know about human cognition. Thus the goal of learning cognitive science at college should emphasize not just the acquisition of the basic knowledge of the science, but also the acquisition of the skill to transfer what they learn in class to real-world settings. To achieve this goal, according to our knowledge on how people learn, the students should be encouraged to develop meta-cognitive skills such as:

1) integration skills to tie experiences to research findings,
2) inference skills to infer social and cognitive models for observed behavior, and
3) inquiry skills to identify research questions, to design and implement tests, and to evaluate the results

These goals suggest that the learning activities should be designed emphasizing hands-on experiences for the students to reflect upon, to help grow meta-cognitive skills from the early stage of their learning. Research results also show that the meta-cognitive skills can be enhanced in collaborative situations, so the students should be introduced to collaborative work situations from the beginning. They should also be encouraged to read research pieces carefully, form his/her own interpretation of them, exchange their ideas with others to clarify their understandings. We are implementing these activities in a collaborative learning environment. Their activities are supported by technology which keeps records of their learning process so that they can collaboratively reflect upon them to become able to take control of their own learning.

Research Findings We Rely On

We design our curriculum based on research findings of cognitive science on how people learn. In order to promote the scientific skills among students, we devise ways by taking advantage of research findings, such as:

1) Experiential knowledge, when accumulated and reflected upon, restructures itself into transferable schema.
2) Constructive interactions provide the participants with chances to reflect on and restructure their own ideas.

It is known in cognitive science that in joint problem solving situations each individual participant works constructively to increases the diversity of solutions, from which the participants cyclically gain different perspectives to generalize their solutions [4][5]. This divergence oriented view suggests that putting the students in constructively interactive sessions can strengthen each individual student's understanding of the materials. Our curriculum thus emphasized constructive interaction throughout the course.

Yet our experiences so far has taught us that the divergence-oriented approach is not intuitively natural for most of the students. The students often think learning should be completed individually, that others in the same class think more or less the same way because they are learning the same materials, and talking to others would not have much to do with their own learning. As described above research suggests that these intuitions are often wrong. They need to be gradually introduced to the practice of working collaboratively with others. Being put in a situation where they have to explain what they thought they understood, they come to realize that they have not understood enough, which motivates them to learn more. They also gradually learn how to ask question of others so that they could know what they need to know, as well as help others realize how they could elaborate their understanding. Because this interaction works better if they have some externalized form of their cognitive processes and of their ideas, we provide them with technological support to keep such records..

Curriculum Structure and Classroom Activities

The present curriculum has been developed for Japanese college students who major in cognitive science at our university. In the first year of the four-year course, students engage in hands-on experiences of simple cognitive tasks and "analyze" what they do, first individually and then collectively. They are also encouraged to think over what they do cognitively, as well as to simulate others cognitive processes. These activities are expected to gradually enhance their meta-cognitive perspectives, their awareness of how cognitive systems work. This experience-based understanding is gradually meshed into introductory reading activities of technical materials in the latter course of the first year. The reading materials include topics touching on their experience and the related topics so that can gradually expand their scope.

The reading activities are done in the jigsaw method throughout the curriculum. In the jigsaw method, each member of a group is assigned a part different from the others' to master and then exchange that information to create a whole understanding as the group. When a separate session is set for securing their understanding of the assigned parts, this setting is called "expert" group activities. An example might be gathering those with the same research piece together to prepare their explanations. The jigsaw method produces a natural setting for each member to be responsible to explain what one understands to others, often motivating them to learn further. The students are gradually introduced to the simple jigsaw of two to three parts at the beginning, to a more complicated and dynamic jigsaw to cover thirty to forty research pieces toward the end of the course. We report how a simple jigsaw and a more complex one are run in class in the latter part of this paper.

In the third and the fourth years they are encouraged to engage in more inquiry-oriented, project-based learning, leading them to graduation research. Students exercise research methodology on selected topics, including process data analyses, simulation model building and naturalistic observations.

Technical scaffolds

We use information technology extensively, mainly to keep records of notes, comments, and concept maps, which are used for reflective purposes. Such records are accumulated over the course and become a shareable knowledge base for the community.

We are devising and testing an electronic note-sharing system ReCoNote (Reflective Collaboration Note) for note sharing and concept mapping and collaborative scrutiny of the notes and maps. Fig. 1 shows an actual product of a sophomore who tried to concept map materials she had covered so far. The logging data reveal that the students visit others notes often, learning from others to improve their own work.

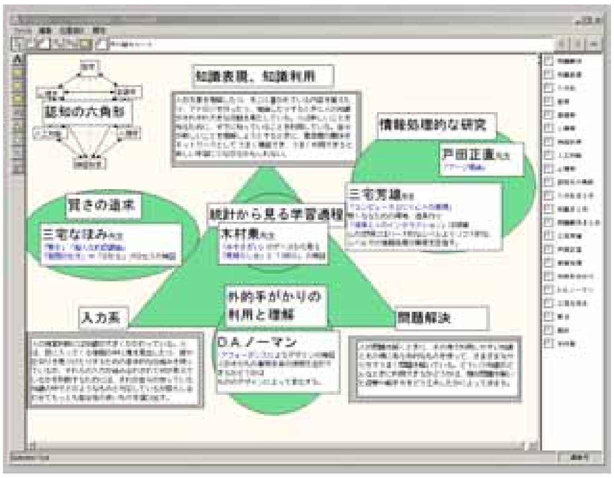

Fig. 1: A sample concept map on ReCoNote

These records are constantly examined for formative evaluation. As part of assessment of our program, we also interview the students six months to one-year after the end of the classes. During such retrospective interviews, the students sometimes come to realize new structures of what they have learned.

An illustrative case 1: Teaching concepts of human memory

In this section, we present a case illustrating our approach where students learned basic constructs of human memory. Students gradually analyzed the research findings on the "semantic net representation" by the "jigsaw" method, and integrated it with their previous experience of analyzing data learned from a classic experiment.

Sequence of Class Activities

In three 90-minute classes of "Cognitive Science & Experimental Design," we required the sophomores to learn three sections on memory from a standard textbook, "Elaborations and their network representations," "Depth of processing," and "Inferential reconstruction in recall." Prior to these, the students had spent five weeks analyzing the main results of a classical sentence memory research, and devising analytic measures.

In the first class, we introduced the three sections on memory. The seventy-eight students were divided into three groups, and each student read one of the three sections. Three students who read different sections then convened to exchange their understanding (the first jigsaw).

In the second class, the students were again divided into three groups to work in separate rooms, to become "experts" on their assigned sections. The students worked with TA's in small groups to answer questions about the hypotheses, experimental designs, results, and implications of the studies. These questions were prepared specifically to have the students focus on critical details of the materials, so that they would be comfortable to be responsible for the assigned piece. They were then asked to summarize the section by rephrasing the summary in the textbook. This step served as a preparatory phase for the second jigsaw.

In the third class, students assembled in one room to exchange their sections, again in the jigsaw method (the second jigsaw). They were asked to integrate the main points of all the sections in order to answer the question, "What is memory?" To conclude, they were asked to reconsider the measures they had used to analyze the Bransford & Johnson's data.

Learning Trajectories

At the first jigsaw half the students stated they did not understand the material, which motivated them to explore further. Then in "expert" groups, they were observed to actively reconstruct semantic nets and extract experimental results from the texts. During the second jigsaw, they used concrete examples more often than in the first class, summarizing them as:

1. elaboration facilitates recall (39%)
   - 1.1. by providing additional retrieval paths in net (19%)
   - 1.2. by permitting recall by inference (23%)
2. processing of meaning promotes elaboration (41%)
3. previous knowledge reconstructs the net (63%)

Forty-two of the 78 students (54%) referred to the concept of semantic net accurately by the end of the class. This percentage is substantially higher than that gained in the classes of traditional teaching.

They also improved their analytic measures. As in Table 1, students adopted measures that value gist recall (e.g., number of Idea Units) or reconstruction (amount of additional information) more often than measures that value verbatim recall (number of correct sentences).

Table 1. Improvement of students' analytic measures

	Verbatim	Gist	Reconstruction
Pre-Jigsaw	62.0%	43.0%	3.8%
Post-Jigsaw	13.7%	68.6%	15.7%

Learning through collaborative reflection enabled them to clearly understand the reasons why people remembered semantic aspects of sentences better than their superficial features. Students also gained meta-cognitive experiences of becoming experts on a piece of literature and grasping its main points. These experiences provided the students with a base to engage in more rigorous constructive interaction in the latter phases of the curriculum. When we interviewed 25 students six months later, they could still verbalize the main points or recreate them from memory.

An illustrative case 2: Tying together a wide variety of research pieces

Another direction we are exploring is to help students acquire skills to tie research pieces together so that they can keep building on their knowledge bases, even after their graduation.

This integration skill is important for almost any profession, but to our knowledge it is rarely taught explicitly, even to college students. We have conducted some basic survey how students do this with little support and found out that they indeed did very poorly [6]. Some detailed analyses of the processes imply that the following three support steps are needed to help students gain the knowledge integration skills. Students need support

(1) to identify details of each research piece, so that they can use it as supporting evidence for claims they make,

(2) to develop self-generated, abstracted statements of research implications, so that they could generalize from there, and

(3) to gradually tie such abstracted statements among similar to less similar research pieces so that they could expand and restructure their knowledge base.

In order to implement these, we have devised a series of jigsaw sessions.

Context

The series of jigsaw methods mentioned here is part of the literature survey course among the undergraduate cognitive sciences curriculum we have been describing here. The students are first introduced to the simplest type of jigsaw early in the first semester and repeat it several times over the following semesters. As they repeat, more and more emphasis is put on expert group performance, to guide them realize that the different people naturally develop different comprehension even with the same reading material, thus jigsaw is more of a natural form of interaction rather than an artificially created setting.

They are then promoted to the dynamic jigsaw session at the end of the second semester of the second year. In this session, each student is encouraged to form a core knowledge base according to his/her own research concern. They select research pieces of their choice from a pool of learning materials, and then form jigsaw with others whose cores are similar to their own. By gradually expanding the scope of the jigsaw, the students are encouraged to practice constructing and reconstructing their own knowledge bases. While they are doing this they are constantly encouraged to use the technology to reflect upon their own knowledge bases by comparing those with others'.

Class activities and learning materials

In a simple jigsaw class, we typically use three to four research elements, and divide the class into the same number of groups as there are learning materials. Each student reads the assigned material to become an expert. Groups are then shuffled to form a jigsaw group that consists of one expert of each learning material. The class could be done in 90 minutes, or could expand over three to four 90 minute sessions, particularly toward the second year where students start to tackle more complex literature. A typical set of learning materials consists of three introductory research pieces, an example case of which might include topics like intellectual curiosity, sensory deprivation, and the extraneous effects of awards on intrinsic motivation. Another set could cover research methods, like one experimental laboratory study, one simulation study, and one observational study, all on the topic of learning, on a shared topic like problem solving.

The illustrative case mentioned above utilized the enhanced jigsaw, where special set of activities are prepared for expert groups, to help the students comprehend the details of the materials. The learning materials can be tightly related to each other, with careful readings of the details, as in the case of the memory study described above. We introduce this method only after making sure that the students are generally aware of the importance of becoming experts for the jigsaw to succeed. Two semesters' practice appears to be the time required for this awareness to be shared among the students.

The dynamic jigsaw class is more structured, and runs across several 90-minute classes. In the earlier classes, the students are introduced to 30 research topics, with simple descriptions for each. Each student selects one or two topics out of this pool and is given the corresponding reading materials. They read them to become experts, and create notes using ReCoNote in order to explain the material to others. The literature pool is structured to cover three topic domains, "Receiving and processing external information (perception in a broad sense)," "Using information (problem solving, memory, sentence processing)," and "Creating information (learning and development)." Students form jigsaws with others who work in the same domain, exchange their explanations and retouch their notes, each covering one domain. Toward the end of the course, the domain jigsaw, which consists of single experts from every domain, is formed and the students are encouraged to exchange their overall view of each domain. They conclude the class by creating the final version of their concept maps, with could potentially cover the entire learning materials.

Assessment results

We have been working on this curriculum for three years, having gradually introduced more and more complex and dynamic types of jigsaws each year. We have completed the entire cycle for the first time last winter (our school year ends in December). We have been comparing their concept maps, both at intermediate and end points during the semesters. The quality of the maps and summary reports has consistently improved, and we are now developing measures to capture the progress. We have also been conducting extensive interview studies, six months to a year after the completion of the courses. This line of assessment has revealed that the students need to be gradually exposed to this type of collaborative activity. They are unsure during the first jigsaws, however simple they are, but come to understand both the strengths ("it provides us with chances to clarify our understanding, because others question us and give us perspective we might miss otherwise," and "we get used to the thinking that each individual is unique in forming her own understanding") and the weaknesses ("unless all work equally hard to participate, the entire group suffers severely," and "time is always too short to explore the depth of the materials").

What We Have Learned So Far

The students have come to grasp the materials better than in the more traditional classes. These data show that the learning is a spontaneous, long-lasting process. Yet we still have little information about how our knowledge becomes structured, how we could externalize it for further learning, and how experiences of solving problems at hand form into coherent, general-purpose, transferable cognitive procedures. These are old questions, to which new data from teaching of cognitive science may bring new insights.

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