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Reconciling Structuring Collaboration and Student Agency

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Abstract: Advancement in supporting knowledge construction creates deeper problems on how to reconcile structuring collaboration with promoting student agency. In order to provide a case study for these problems, we used an instructional method, the "Knowledge Constructive Jigsaw", as an external macro-script in a science lesson and analyzed pre-, post-lesson answers and a 15-minute discussion by three seventh graders. We captured knowledge sharing and individual construction by adapting a framework, a "function mechanism hierarchy", and a dual-unit analysis at a group and individual level. The results indicate the reconciliation, that is, the students shared knowledge pieces while constructing their own knowledge, for which a coupling between the coarse-grained script and well-organized materials appeared responsible.

Introduction

As the learning sciences advances its refinement in supporting collaborative knowledge construction, it poses deeper problems on how to reconcile *structuring collaboration* with *promoting student agency*. This paper provides a case study to show that structuring collaboration towards the teacher's expected outcome does not necessarily hinder but promotes student agency, or the self-organizing character of knowledge construction. Along with the conference theme of "reflecting the past and embracing the future," we reflect upon a discussion between two approaches of scripted collaboration and Knowledge Building (Bereiter et al., 2017), provide our case study wherein three junior high school students deepened their understanding in their own way and also successfully shared knowledge as a group in a science lesson, and examine which elements of lesson design are responsible for reconciling the two aspects of knowledge construction for future practices.

In the discussion above, experts in Knowledge Building welcomed a change in the views of *scripts* as *rigid, prescriptive cognitive structures* to *flexibly adaptive group supports* for facilitating the use of learners' internal scripts, while experts in script theory adopted more socio-cognitive views into classroom learning (Vogel, Wecker & Kollar, (2017). Thus, the notion of flexibility, which Dillenbourg & Tchounikine (2007) once analyzed conceptually, needs to be examined in actual socio-cognitive processes. For example, setting a common task and providing materials may constrain learners' interactions into a corridor towards expected outcomes, but in reality, each learner may construct her or his own knowledge through the interaction. In order to reveal such an intricate relationship between constraint and self-organization, we need to collect data from a lesson wherein learners are motivated to share knowledge to achieve a common goal and analyze learning processes by mapping their writings and utterances onto a knowledge framework and using both units of analysis of the individual and the group.

Instructional method: Knowledge Constructive Jigsaw

We take group learning in the lesson conducted by the "Knowledge Constructive Jigsaw" (hereafter "KCJ") method (Miyake, 2013) as an example. The KCJ consists of five learning activities: (1) writing an answer to the day's given problem, (2) an expert-group activity which allows each individual learner to accumulate pieces of knowledge relevant in solving the problem, (3) a jigsaw-type activity where learners from different expert groups get together to exchange and integrate the pieces of knowledge and form an answer, (4) a crosstalk activity where the learners exchange their ideas for solutions, involving the entire class, and (5) writing down an individual answer again to the same problem. This method distributes knowledge among the learning partners in Step 2 for integration in Step 3; however, it places greater emphasis on the role of a shared "problem" for knowledge construction by adding Steps 1 and 4, as well as that of the conceptual changes of each individual by adding Steps 1 and 5. The method is considered to be an *external macro-script* like the Jigsaw (Dillenbourg & Jermann 2007), and we do not predict how the script is enacted in a particular situation as it is coarse-grained enough to allow learners' self-organization of knowledge and discussion.

Analytical method: Function-mechanism hierarchy and dual-unit analysis

The series of activities above enables us to compare students' dialogues with writings: for example, the former in the jigsaw activity of Step 3 with improvements in the latter from Step 1 to Step 5. We bring in two analytical methods to take advantage of this feature: a "function-mechanism hierarchy (FMH)" (Miyake, 1986) and a dual-unit analysis. The FMH is a hierarchy that consists of two types of knowledge: function and mechanism, which

is suitable in clarifying the detailed structure of the lesson and knowledge construction by the learners. The dual-unit analysis is to analyze the same data using two units of analysis: the individual and the group. Saito and Miyake (2011) demonstrated that, when analyzing a collaborative process sequentially, the selection of knowledge pieces, time of reference and order vary from learner to learner; however, when analyzing it in an aggregated way, most of the pieces are referred to by most learners while the rest are referred to by only a few learners.

Research questions

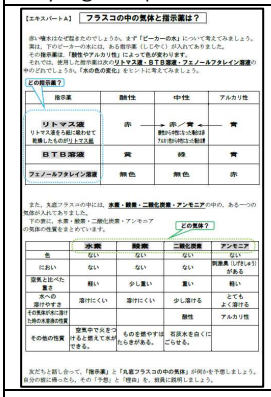
A combination of the instructional method and the two analytical methods enables us to capture a convergent, knowledge-sharing aspect constrained by the macro-script and a divergent, individualistic knowledge-construction aspect that goes beyond what is given in the situation. We predict that a set of the "problem (jigsaw task)" and "expert materials" strongly constrains students' knowledge sharing, especially when knowledge pieces are explicitly presented and hierarchically organized, while the students differ from each other in knowledge construction by connecting and weighing particular pieces, especially when fewer prompts for discussion or scaffolds for writing are presented, that is, *unscripted*. Thus, our first research question is, "Are the knowledge pieces of expert materials successfully shared among the three students through the jigsaw activity?" and the second one is, "Do the three students differ from each other in the number of references to knowledge pieces and relation-making among them both during the jigsaw conversation (Step 3) and post-lesson writings (Step 5)?"

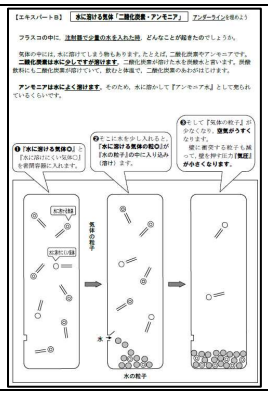
Method

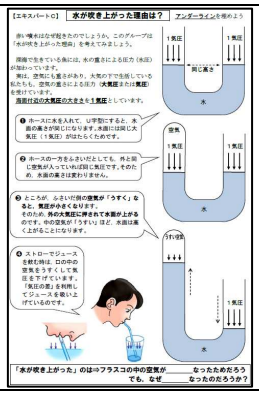
A veteran junior high school teacher, a partner teacher in the authors' project, conducted a KCJ lesson in Grade 7 science ("Generation and the nature of gas") for 19 students. The teacher demonstrated an experiment in which a transparent solution in a beaker was vigorously pumped up through a glass tube into an upside-down, sealed, round-bottom flask, which turned red when he injected a small amount of water into the flask with a syringe. He posed the day's problem and each student wrote his or her answer on an *unscripted* worksheet. Then, the students engaged in the activities of Step 2 through Step 4 in 50 minutes. The teacher prepared materials for the expert activity and a whiteboard for the jigsaw activity, from which he expected the answer below (Figure 1).

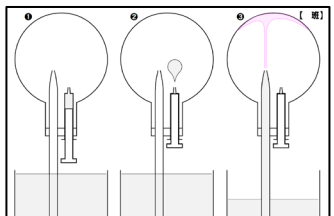
We handed out a headset microphone and IC-recorder to each student, collected voice data, and transcribed it by hand for the analysis. We also collected students' answers before and after the lesson to analyze whether they referred to the points shown in Figure 1. Out of six jigsaw groups we chose one group which consisted of Alpha, Bravo and Charlie (assumed names which mean Alpha was assigned expert material A, Bravo for B, and Charlie for C). We chose this group since they proposed high-quality explanations at the level of

Day's given problem "How did this red fountain occur? What is the mechanism?"









A: Gas and indicator	B: Solution in water	C: Solution blow-up	Whiteboard for the Jigsaw activity

An expected answer should include the four points below:

1. At the onset, "ammonia gas" was injected into the flask; "phenolphthalein solution" into the beaker (Material A).
2. When the water was injected into the flask with the syringe, the ammonia gas, being very soluble, melted into the "ammonia water" and the air pressure in the flask was reduced (B).
3. When the pressure in the flask was reduced, the water in the beaker pushed by the outside atmospheric pressure rose up the glass tube and a fountain occurred (C).
4. Since a phenolphthalein solution was in the water, entering the flask from the beaker, it reacted with the "alkali" of the ammonia water and the fountain became red (A).

Figure 1. Expert materials, worksheet for the jigsaw-type activity and expected answer for the targeted lesson.
molecular motion in Step 4 and all of them wrote the four points in the expected answer in Step 5.

Figure 2 shows the FMH for the lesson. The functions are shown in circles as F, indicating knowledge pieces of facts and phenomena. The mechanisms are indicated in rectangles as M, describing explanations of "how and why that happens" by connecting the functions with each other. The mechanism of the red fountain (F0-1) can be explained by the combination (M1) of the water injection (F1-1), ammonia gas (F1-2) and phenolphthalein solution (F1-3). Yet, if someone questions why the transparent materials turned red, the answer requires another level of explanation such as the chemical one at level 2. Likewise, the function at level n requires the mechanism at level n+1 in a repeated way. By mapping pieces of information contained in each expert material onto the hierarchy with bold alphabet letters A, B and C (when it was implied, they were indicated by letters in parentheses), you can see that most knowledge pieces were explicitly presented and hierarchically organized with each other.

We also analyzed the students' pre and post lesson answers and the 15-minute jigsaw dialogues using FMH: first, dividing each sentence into *content word* and *function word* (connectives, pronouns); and second, mapping the former on the framework as referring to the knowledge pieces and the latter as relation-making among the pieces. The total number of utterances of the group was 596.

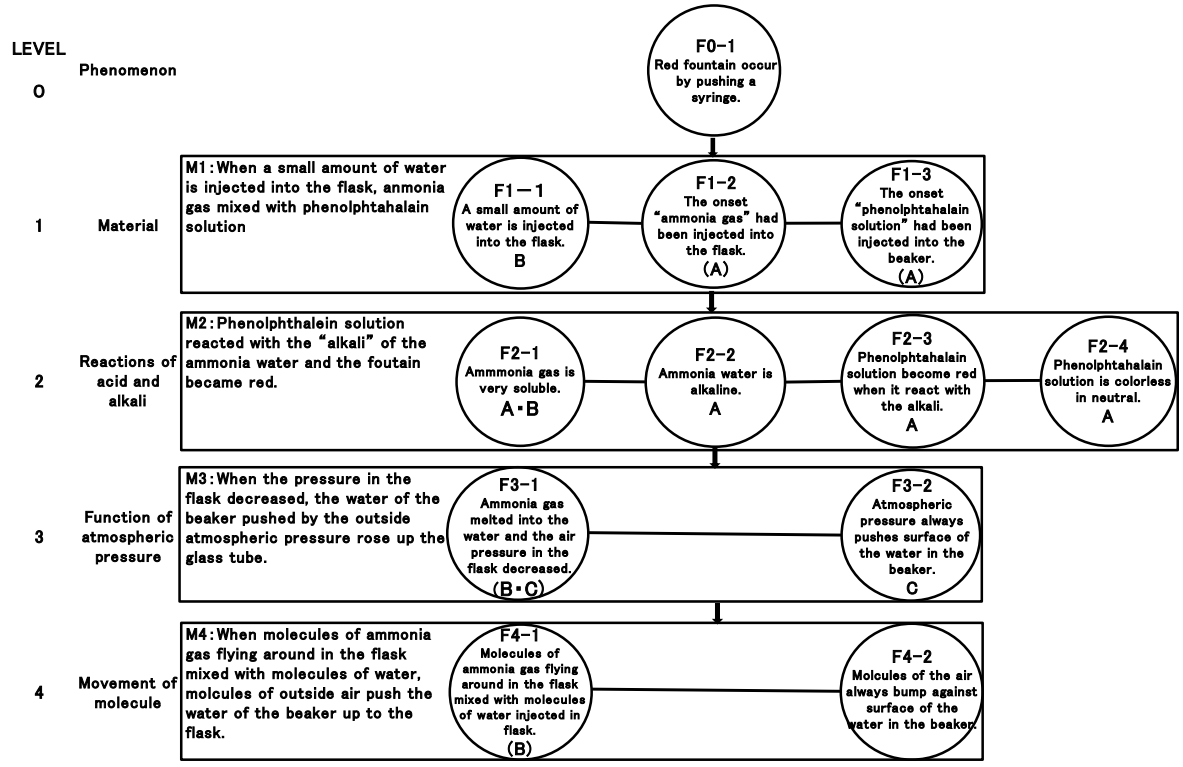


Figure 2. Function-mechanism hierarchy for the red fountain problem

Results and discussion

When we analyzed the pre- and post-lesson (Steps 1 and 5) answers of 12 students whose worksheets were collected, we found that their coverage rate of the four points in the expected answer improved from 3.2% in Step 1 to 87.5% in Step 5. Despite the fact that the lesson was conducted at the beginning of the unit and the students knew little about the content, the improvement was big enough to conclude that the class achieved the goal.

Table 1 shows the result of the detailed analysis of the target group. The column "Knowledge" indicates knowledge pieces shown in Figure 2, and the columns of the "Pre-lesson answer", "Jigsaw activity" and "Post-lesson answer" represent whether each student referred to, repeatedly referred to, or linked each piece with another. If we look at Table 1 in an aggregated way, eight out of 12 knowledge pieces were shared among the three students through the jigsaw activity, and seven out of the eight pieces referred to were utilized in the post-lesson answers. Considering the fact that they referred to only one knowledge piece in the pre-lesson answers, we can say that all the members improved their understanding towards a common goal by sharing the knowledge pieces. Taking a closer look at Table 1, however, individual differences are revealed in both the jigsaw activity and post-lesson answer. Alpha referred to nine knowledge pieces during the jigsaw activity and constructed her post-lesson answer by connecting the pieces about the gas and indicator (Levels 1 and 2); Bravo referred to nine pieces and

constructed her explanation around two points such as the injection of water (F1-1) and the reduction of pressure (F3-1, F4-1); Charlie referred to ten pieces and broadened connections across all levels in his post-lesson answer.

The results indicate that while the knowledge pieces of the expert materials were successfully shared among the students through the jigsaw activity, they differ from each other in the number of references to knowledge pieces and relation-making among them from the jigsaw activity to post-lesson answers, as if they had walked down the corridor towards expected outcomes while constructing their own knowledge through interaction with others. It is implied that the constraint caused by the macro-script makes diversity and agency flourish in finer levels of knowledge construction. In this particular lesson, a coupling between well-organized materials and coarse-grained scripts without strict control or guidance appeared responsible for reconciling structuring collaboration with student agency. Yet, we do not intend to generalize this result from only one case, especially because another case under analysis suggests that a pattern of role exchange among member influences both the convergent and divergent knowledge construction process. Rather, we would like to claim that not only controlled experiments but also in-depth analyses of knowledge construction processes contribute to clarifying the intricate relations between constraint and self-organization and designing lessons for deeper learning.

Table 1: Reference and link of knowledge of three students in the lesson

Knowledge	Pre-lesson answer			Jigsaw-type activity			Post-lesson answer		
	Alpha	Bravo	Charlie	Alpha	Bravo	Charlie	Alpha	Bravo	Charlie
F1-1(B)	○	○	○	○+	◎+	○+	○	○+	◎+
F1-2(A)	—	—	—	◎+	◎+	◎+	◎+	○+	○
F1-3(A)	—	—	—	◎+	◎+	◎+	◎+	○+	○+
F2-1(A,B)	—	—	—	◎+	◎+	◎+	◎+	—	◎+
F2-2(A)	—	—	—	○+	◎+	◎+	◎+	○+	○+
F2-3(A)	—	—	—	◎+	◎+	◎+	○+	○+	○+
F3-1(B,C)	—	—	—	○+	◎+	◎+	○+	◎+	○+
F3-2(C)	—	—	—	○+	○+	◎+	○+	○+	◎+
F4-1(B)	—	—	—	—	◎+	○	—	◎+	◎+
F2-4	—	—	—	◎+	—	—	○+	○	○+
F0-1	—	—	—	—	—	—	—	—	—
F4-2	—	—	—	—	—	—	—	—	—

○ Reference, ◎ Repeated reference, — No reference, + Link

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