Learning Science in Communicating Science and Technology In-the-making: A Case Study of the 'Science and Technology Mania' Award Program

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Abstract: The 'Science and Technology Mania' award program is an annual nationwide award activity organized to provide teenagers with opportunities for engaging in a high-technology-based long-term project work. The task involves designing a model ship propelled by the Lorentz force (a Lorentz ship) that allows diverse approaches irreducible to one right answer, and thus adopts features of science and technology in-the-making. In this study, we attend to opportunities for learning science that the uncertain aspects of artifact-designing project provide with participants, particularly when students communicate with scientists about their design practices. We analyze oral presentation sessions of the program and articulate two findings. First, students articulate embodied knowing in the presence of scientists. Second, students enact discursive resources deployed in concrete action. We conclude that students' design practices constitute referent that communication is directed toward and therefore become resources for developing scientific discourse.

Key words: award program, in-the-making, communication, Lorentz ship, artifact-designing.

I. Introduction

From sociocultural and sociolinguistic perspectives, science denotes not merely a set of concept words, but a form of culture with its own particular languages and practices. Thus, knowing science means knowing ways of acting appropriately in this particular culture(e.g., Pickering, 1992). Learning then emerges in the course of participating in cultural practices and talking about associated issues with various linguistic resources(e.g., Lave & Wenger, 1991). Conceptualizing knowing and learning as cultural performance presupposes that an individual action does not remain at the level of individual, but always involves intersubjective dimensions—an individual action is performed on the presupposition of intelligibility to the other and therefore it has communicative value. It may look like that communication is not an explicit goal of collective performance in many cases because communication constitute *an* aspect of collective human activity. However, communication constitutes a central aspect of knowing and learning science because communicative value is integral to any concrete action that science educators would point at as evidence of scientific knowledgeability. Therefore, an important task of science education is to design activities that involve collaborative interaction of accomplishing collective motives and thereby situate communication as central aspect of participation in scientific practice.

Authentic science, a term science educators often use to refer to aspects of cultural environments that fits for the nature of science and technology, takes uncertain aspects of doing and talking science as important conditions for it. In the case of scientists and engineers, their ongoing practices are full of uncertainties at every moment of setting problems, planning to find answers, collecting data, and interpreting data. They oftentimes proceed without exactly knowing what they are looking for and how to find it. Their languages are flexible and evolve as they figure out controversial issues. Communication occurs in such a way to allows them to navigate new research areas until they describe objects under investigation

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satisfactorily. These uncertain aspects embodied in scientific and technological (discursive) practice contrast to doing and talking science that most of school practices performs in stabilized forms, as the notion of 'science in-the-making' is differentiated from 'ready-made science'(Latour, 1987). Therefore, science educators propose that students' real experiences of dealing with uncertainties would be essential to deep engagement in scientific tasks and improvement of their ways of communicating science.

Traditionally, award programs that various institutions of science and technology education organize for young students have taken roles of supporting students' opportunities for experiencing science and technology in-the-making and thereby participating in communications different from those of schools. Some science educators research about educational values of public award programs and report that students, teachers, and organizers gave positive evaluation on their achievements(e.g., CREST [Woolnough, 1994]). Yet, little is known about what is really going on when students are engaged in larger contexts of doing science, what communication they make with others, and how they learn in the process. In this study, we draw on our experiences of hosting a nationwide 'Science and Technology Mania' award program and articulate an aspect of learning science that emerges from design projects that middle and high school students direct as part of their participation in the program. In particular, we attend to configurations of communication that are created by uncertain aspects of project works (science and technology in-the-making) and therefore take the feature of communication in-the-making. In what follows, we describe our research context that leads us to find 'in-the-making' as a concept relevant to understanding students' practice in our science program. Then, we present our two salient findings of communication in-the-making and associated learning supported by interpretive analyses of concrete case materials.

Ⅱ. Research Context: Science and Technology In-the-making

'Science and Technology Mania' award program was hosted from August 2005 to January 2006 by Science Education Research Center stationed at one university in Seoul. The purpose of the program was to provide teenagers with opportunities for enjoying science and thereby increase their interest in science and technology. Recent trends of students' low preference to science, represented by strong avoidance of science- and engineering-related jobs constituted a background to the commencement of this public event under the auspicious of government and other science culture organizations(Choi, 2006). The program was intended particularly for science-motivated students so that their interest in science and technology could be developed even toward a level of 'mania.' The main task of this program is to design a high-technology based scientific artifact called a Lorentz ship, a hand-made model ship propelled by the Lorentz force built with (electro-)magnets and batteries in a structure that is less than both 20 centimeters wide and 40 centimeters long(see Fig. 1). Three students and one teacher constituted one team and participated in the program.

The program proceeded through the following steps: First, the nationwide announcement was made through both on-line and off-line media. The information was available on the Internet homepage of the host center and through other well-known non-profit organizations for science education and culture. The metropolitan and provincial offices of education of Korea assisted distributing the announcement to individual schools at their local areas. Second, one hundred sixty five teams(19 teams at middle school and 146 teams at high school level) submitted applications. Third, one hundred sixty teams parti-

Fig. 1 *A simplified model of a Lorentz ship*

cipated in the workshop that consisted of lectures and a hands-on session, and therefore functioned as a half-day orientation session. Two invited university professors gave lectures on the physics of the Lorentz ship and an introduction to naval architecture. After the two lectures, students made a simplified Lorentz ship model with materials given by the host and had it move across tested it in the salt water. The simplified Lorentz' ship model was constituted by one bar-shaped ceramic magnet, two thin metal strips in each parallel side of the magnet, and a nine-volt battery connected to the two produces(See Fig. 1). Put in 3.5% salt water, the metal strips work as positive and negative electrode between which salt ions(Na+, Cl-) move and thus produce electric currents. At the same time, the electric current flowing around the bar magnet produces a third force called Lorentz' force that acts on the ship which is perpendicular to the current and the magnetic field. Students were asked to use this model and develop their own ships that would make faster movements. Fourth, one hundred forty teams(a total of 500 students and teachers) submitted their final reports and participated in the final program consisting of oral presentation session and tournament racing (see Fig. 2). A panel of judges consisting of fifteen university professors and expert engineers observed the students' 10-minute presentations and asked questions. Finally, Grand, Gold, Silver, and Bronze awards were granted to the seven excellent teams in the high school division and six teams in the middle school division.

Fig. 2 *Two sessions of final program: (a) oral presentation and (b) tournament race.*

Science educators have proposed technological artifact-designing as a way of realizing 'science and technology in-the-making' in school settings(e.g., Roth, 1998). In the artifact-designing activity, the process and its consequential product are not pre-determined, but become what they are as they unfold in and through designers' concrete practice. Designers are confronted with uncertainties all the while they develop ideas and artifacts by means of cultural resources such as materials, tools, and scientific concepts available within communities(Hwang & Roth, 2004). The 'Science Technology Mania' award program is evaluated as taking features of science and technology in-the-making in the following three points: diverse approaches to the task, historical development of outcome, and ongoing conversations within community. First, the task of designing a model Lorentz ship allows diverse approaches that are not reduced to one right answer. Students made variations of the simplified model ship and attempted to develop an optimized artifact that affords the fastest movement. Despite the clear basic principle (Lorentz' force), there are many empirical factors affecting the direction and the speed of the Lorentz' ship. For example, students find that increasing the number of batteries or using an electromagnet could afford a high voltage between two electrodes, but at the same time increase the total weight of the ship. Second, the openness of the task allows students' long-term engagement in the same task and thus historical development of the design. The hosting center decided to propose the same task in the second program, which gave students opportunities for redesigning or developing previous year's outcomes. Some students had experiences of participating in the previous year's or attended the same schools as those of previous year's participants. As the previous year's awarded artifacts were available through the workshop, participants attempted to learn about them and propose improved artifacts. Therefore, some artifacts were equipped with newer technologies(e.g., wireless control panel). Third, the participating students constitute community in which lively discussions occur through the internet homepage and mailing service. Students, physicist, engineers, and the host center communicated issues and therefore constituted a temporal community of practice.

Ⅲ. Data Analysis

Case materials presented in this study came from the database developed through an ethnographic methodology. To gain better understandings of students' learning in a setting given at hand, we video-recorded the entire process of collective events using three 6mm camcoders. They include students' works at workshop, tournament race, and oral presentation. We digitized about fifteen sixty-minute-long tapes using a video-editing computer program for detailed analyses. Students' reports, presentation slides, and formal/informal on-line messages constituted the other part of the database. Particularly, the oral presentation session appeared as an important focus of our study. In the session, students were debriefed by expert physicists and engineers. Students explained how they approached the design task, what their design outcome is, and what they learned in the process. Because neither scientists and nor students have yet known what would ultimately be revealed to the best artifact, the former had to attempt to understand what students have performed to design a presented artifact and the latter had to provide resources for understanding. That is, the oral presentation session constituted a real context in which students participate in legitimate discourse of physics on the ground of their own practice.

Sixty oral presentations that covered one third of the total were available for analysis. The authors watched video clips repeatedly with the intention of understanding configurations of communicative interaction in-the-making and learning that uncertain aspects of design activity makes possible. We singled out exemplary cases and transcribed them (the translation into English presented in this paper is our own). We articulated working hypotheses individually and collectively pertaining to opportunities for learning science from selected case materials.

Ⅳ. Case Studies: Communication In-the-making

In this section, we draw on recent science education research on communication and present two salient aspects of learning science that appeared repeatedly throughout our interpretive analyses of communication in the oral presentation session: first, students articulate embodied knowing in the presence of scientists and second, students enact discursive resources deployed in concrete actions. We provide concrete case materials and support theoretical analyses.

1. Students articulates embodied knowing in the presence of scientists

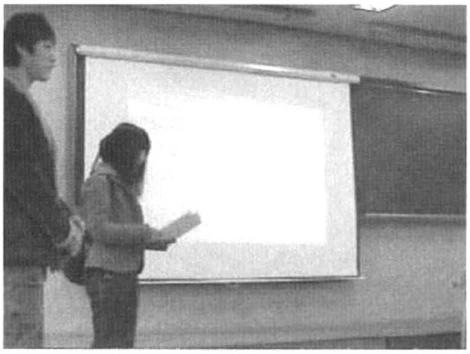
The significant aspect of communication observed at the oral presentation session was the role of the human body that articulates knowing and learning in material forms. In terms of 'embodied knowing,' we denote that our analyses are not limited to the speech act, but include all kinds of act that the body takes in and for communication(e.g., eye gaze, gesture, body orientation [Roth, & Pozzer-Ardenghi, 2006]). This approach allows us to take a phenomenological stance that integrates implicit aspects of knowing—knowing exceeding what one can tell.

The following conversation between a group of students and a physicist exemplifies articulation of embodied knowing in material form. The episode occurred immediately after the students completed their ten-minute presentation to three panels, one of whom was the physicist.

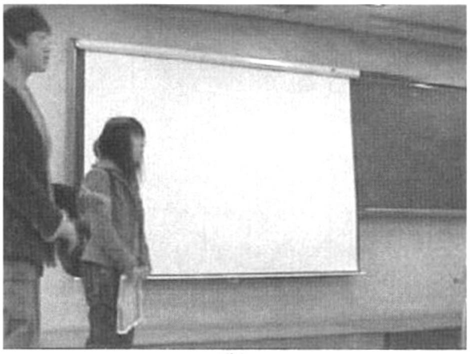
In this situation, the physicist asks how they could keep the voltage same and change only the current (turn 01). Student 1 says that they used "voltage apparatus", and thereby completes the physicist's utterance as the question about experimental setting (turn 02). The physicist asks again almost literally the same question (turn 03). The student repeats

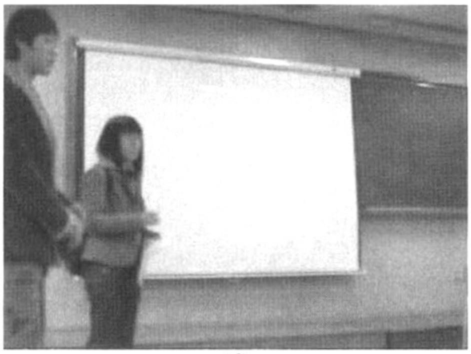
Episode 1[1]

01 Physicist: you said current affects more than voltage, how did you increase current while keeping the same voltage?
02 Student 1: we used a voltage-apparatus in the experiment
03 Physicist: I mean, how could you make the current bigger at the same voltage?
04 Student 1: [we] used the voltage-apparatus
05 Physicist: voltage apparatus [1(???)
06 Student 2: [1((He stretches his left hand))
07 Student 3: [1increased the number of batteries
08 Physicist: then, the voltage increases
09 Student 1: using the voltage-apparatus, keeping voltage same, the same voltage and the current (???)
10 Physicist: you mean, a parallel connection?
11 Student 1: we connected in series
12 Physicist: then the voltage (will change?)
13 Student 1: we did not use [2batteries but the [3voltage apparatus
[2((She gestures a line with her right hand))
[3((She gestures at a rectangle with her hands))


(a)


(c)


(b)


(d)

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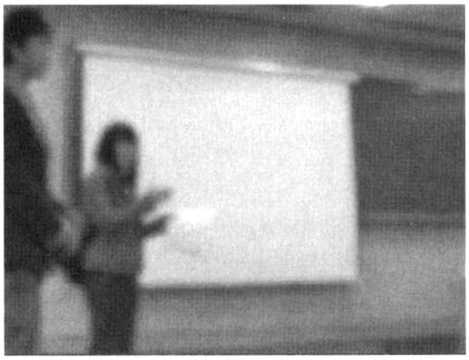
[1] The transcription conventions were used following the method of conversation analysis(ten Have, 1999).
((He stretches…)): Salient actions are noted and enclosed in double parentheses;
.;?: Punctuation is used to indicate characteristics of speech production rather than grammatical units;
(???): Question mark in parenthesis indicates inaudible utterance(s);
[: Sqaure brackets in consecutive lines indicate beginning of overlapping speech or action;
[we]: words enclosed in square brackets are added by authors in the process of translation.



(e)

Fig. 3 *A group of participants consisting of three students gives an oral presentation. Student 1 denotes the girl standing right next to the screen, Student 2 denotes the girl standing the other end of the screen, and Student 3 denotes the boy beside the presenter.*

that she used the voltage apparatus (turn 04). The physicist makes an utterance, beginning with “voltage apparatus” (turn 05), but immediately, Student 2 gestures with his left hand (Fig. 3b) to intervene. (turn 06). He seems to want to talk about something. At the same time, even before Student 2 goes to a next action, Student 3 takes a turn and says that they increased the number of batteries (turn 07) (Fig. 3c). The physicist points out that in that case, the voltage would increase and cannot remain the same (turn 08). Student 1 talks about the voltage apparatus again that is, their voltage apparatus can keep the same voltage (turn 09). The physicist asks if they made a parallel connection (turn 10). Student 1 responds that they made a connection in the series (turn 11). As the physicist points out the voltage again (turn 12), Student 1 specifies that they used the voltage apparatus, not batteries (turn 13). She gestures a series connection by moving her right hand horizontally (Fig. 3d), and then a rectangle shape with both hands (Fig. 3e).

This episode exemplifies that communication with experts about their own design practice provides students with opportunities to articulate their embodied knowing. In their ten-minute presentation, students argued that “the strength of current affects more the magnitude of the Lorentz' force rather than that of the voltage” (Fig. 3a). In this situation, the physicist asks how they controlled the current and the voltage in the experimental setting, and thereby attempts to understand the argument that student provided to explain their design project. The presenter (Student 1) replies by saying ‘voltage apparatus.’ The term might refer to something specific in her design practice, but it does not seem to provide relevant answer to the physicist's question. His repetition of the same question shows that the answer does not make sense to him. The student responds again, but her utterance includes no further articulation. At this moment, the other two students attempt to assist the presenter (turns 06-07). Student 3 talks about batteries. However, her utterance contradicts with the presenter's argument that they kept the same voltage. Student 1 persistently says that she used ‘voltage apparatus.’ Now the physicist changes his question concerning the kind of connection, that is, whether it was in parallel or in series. The presenter says they made a series connection. The physicist points out that this connection would contradict with keeping the same voltage. The contradiction becomes salient to the presenter and leads to the specification of all the experimental practices that she had performed. At the same time she says, ‘we did not use batteries but voltage apparatus,’ she at first gestures at a configuration of several things connected in series (Fig. 4.d), and then a rectangular configuration that specifies ‘voltage apparatus.’ The iconic gesture articulates her embodied experience of experiment that involves her knowing related to make an electric circuit; however, this gesture is not intelligible to the physicist. That is, the episode shows that the students' attempt to communicate with the physicist about their own experiment leads the students' material bodies to produce not only sound object, but also gestural forms of communicative resource. The students articulate their design practice in forms of not only utterances(words), but also gestures(non-verbal body movement).

Asymmetry between student and scientist could be an important explanatory factor in the materialization of embodied knowing. Scientists are commonly expected to demonstrate much more expertise than students in scientific matters; therefore, they tend to talk about science rather than asking questions. However, in this oral presentation session, we observed many of the scientists asking students many questions concerning the structures of model ships and their reasons for doing so. Because they have not participated in students work, and because they are looking at only final artifacts, they have to ask and listen to what the students say. The students have to articulate as much as possible, so that their talks are intelligible not only to themselves, but also to the scientists. Thus, in another example, when asked about a structure of electrodes, the students provide a long explanation as to why they had bent copper plates and had put them closely together. Their gestures showing difference distances between the plates and magnetic force produced in each case could be understood as their attempts to be intelligible by enacting embodied knowing. Once materialized, embodied knowing is available not only to the other, but also to oneself, and thereby becomes material resources in moving toward improved understanding. The students' materialized action serves as grounds for scientists to use their expertise as a resource for communication.

2. Students enact discursive resources deployed in concrete action

The development of materialized embodied knowing to discursive practice constitutes another aspect of learning science that emerges salient in our analysis of the oral presentation session. It is reported that when students talk science in the presence of relevant phenomena, scientific language emerges from gestures and manipulations as a form of communication (Roth, & Lawless, 2002). In the case of oral presentation session, communication with scientists is revealed to provide students with opportunities to participate in the legitimate discourse of physics and develop their discursive practice by drawing on resources made available through concrete actions. The ensuing situation of Episode 1 exemplifies this case.

The physicist asks the presenter (Student 1) what the voltage apparatus is, that is, what she is referring to in terms of voltage apparatus (turn 14). She utters something that is inaudible to the analyst (turn 15). Student 3 says power supply and thereby articulates that they are talking about a power supply they used in their experiment (turn 16). Immediately, Student 1 repeats saying 'power supply' (turn 17). The physicist points out the model ship and asks if students put a power supply inside of the ship (turn 18). Student 1 specifies that their experimental setting was different, which means that they used a power supply for their experimentation, but their final artifact uses batteries instead.

In Episode 1, the physicist attempted to understand what experiment the students had conducted in their empirical settings. This communication led to articulate that the students did not use batteries in the experiment. In this situation, the issue continues. The physicist asks what is the voltage apparatus that Student 1 discursively makes available to him. For a physicist, 'voltage apparatus' might not be a scientific term that makes good sense to him. However, he has to ask by referring to the term if he wants to specify what students presuppose in the talk. Students 3 assists Student 1. He says 'power supply' and thereby makes a new discursive resource available to people present in the room. Student 1 repeats the word in her utterance; thereby, the new resource materialized in the concrete action becomes part of the next action. Concrete human actions deploy and enact a new resource, which science educators call learning and enculturation. In the next turn, physicist asks whether the students used a power supply in their model ship. His utterance not only shows his attempt to understand student's model ship, but also exemplifies a legitimate use of the term 'power

Episode 2

14 Physicist: what is the voltage apparatus?
15 Student 1: (???)
16 Student 3: power [4supply
17 Student 1: [4power supply
18 Physicist: did you put a power supply here?
19 Student 1: no, we made a different setting when we experimented

supply'. Student 1 draws on the term 'power supply' in her discursive action and thereby materializes her embodied knowing in discursive form. In consequence, a form of scientific description of students' practice emerges in such a way to be intelligible to a particular scientist and therefore legitimate within scientific communities in general.

Many other cases of deploying and enacting discursive resources of science (e.g., unit of magnetic field, forces working on a model ship, structural features of a model ship, etc.) came about when scientists ask about students' work and students answer to scientists' questions. The main responsibility of scientists in this presentation session was not in teaching specific scientific concepts, but evaluation of students' work. However, the more scientists attempted to understand students' work, the more their expertise became resources for communication—for some it was not the case because they were interested only in finishing the evaluation as soon as possible. Therefore, learning was ubiquitous in practice of communicating science, and contingently rather than as an outcome of the instruction in this program.

V. Conclusion

In this study we articulated aspects of learning science that emerges from communication with scientists about artifact-design practice that students conducted as part of their participation in the 'Science and Technology Mania' award program. Uncertainties involved in the practice of designing 'Lorentz' ship' drove students and scientists to engage in 'communication in-the-making' of which educational value is summarized by two findings. First, students articulate embodied knowing in the presence of scientists. Second, students enact discursive resources deployed in concrete action. Students' design practice constituted referent that communication is directed toward and therefore became a resource for developing scientific discourse. Our study is significant in that it reveals a mechanism by which learning science occurs in the process of engaging in collective activities. Therefore, aspects of learning science presented in this study contributes to improve science educators' understanding the value of long-term science projects and associated award programs organized by out-of -school institutions.

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