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Changing Science Classroom Discourse toward Doing Science: The Design of a Game-based Learning Curriculum

Mingfong JAN, Yam San CHEE & Ek Ming TAN
Leaning Sciences Laboratory, Nanyang Technological University, Singapore
mingfongjan@gmail.com

Abstract: This paper presents a game-based learning program designed to foster classroom discourse toward doing science with language. Both schools and professional science communities practice science, but the beliefs guiding their practices and discourse patterns are significantly different. In schools, students talk about science in order to learn the ready-made science. In professional science communities, scientists use and develop language as tools for constructing scientific knowledge. In order to transform the discourse practice in the mainstream science classrooms as doing science with language, we design the Legends of Alkhimia 3D role-playing game and curriculum.

Keywords: science discourse, science education, game-based learning, design-based research

1. Introduction

What should students learn in order to be literate in the 21st century? One of the more compelling arguments about the literacy skills of the 21st century is the ability to innovate and produce knowledge like working scientists [14]. Teaching young people to perform like working scientists may be seen as a productive trajectory that prepares them to be literate in science in the 21st century in which reading and writing skills are no more seen as sufficient for a globalized knowledge economy. In this paper, we conceptualize how schools may engage students in performing like working scientists through discourse practice. In particular, we focus on how the design of a game-based learning program—The Legends of Alkhimia game and curriculum—may engage students in *doing science with language*. Doing science with language utilizes language to construct scientific knowledge. It differs considerably from the mainstream science classrooms discourse—using language to talk about ready-made scientific knowledge.

2. Conceptual Framework

2.1 Community Discourse Practice

Discourse, or language-in-use, is a major medium that characterizes a community of practice [8]. Therefore, examining the discourse practiced by a community channels our understanding of its core practice. We examine the discourse patterns in science communities and in the mainstream classrooms in order to understand how we may design a science classroom that engages students in the practice of science with language.

2.2 Discourse Patterns in the Communities of Working Scientists

The discourse practiced by scientists may be characterized as *doing science with language* [7], [11]. In doing science with language, scientists develop specialized language and use language as a tool for supporting knowledge construction activities, such as observation, comparison, evaluation, hypothesis, generalization, design, discussion, etc. The following aspects of doing science with language depict three salient features of this language action tool:

1. Using language as a tool for scientific knowledge construction [7], [11]. Central to this particular language tool is its functions in serving scientific inquiry, which can be further delineated as questioning, hypothesizing, evaluating, and theorizing, etc.
2. Using argumentation as a tool for validating knowledge construction [6], [10]. Scientists use language to develop and examine their proposed theories/claims. In particular, language is used to examine the accountability of evidence, articulate the relationship between the proposed theory and its evidence/data for alternative interpretations.
3. Using language as a tool for evaluating the constructed scientific knowledge. The underpinning epistemology of doing science with language is both constructive and evaluative [5], [10]. When scientists use language to construct knowledge (such as inquiry), they evaluate the knowledge construction process at the same time.

2.3 Discourse Patterns in the Mainstream Science Classroom

Students' practices of science in the classrooms differ noticeably from that of working scientists. The prevalent discourse pattern in the mainstream science classrooms may be characterized as *talking about science* [11], [7]. Talking about science means that students talk about ready-made science contents and often bypass the processes through which the scientific theories are constructed.

In the mainstream classrooms where direct instruction is a norm of pedagogy, students often do not learn science by doing science with language, such as making arguments. When there is a discourse exchange in the classroom, it often takes the form of simple questioning and answering between students and the teacher [11], with the teacher providing one-sided answer that tends to reinforce science as "unmitigated rhetoric of conclusions" [13].

The Question-Answer-Evaluate (QAE) or Initiate-Response-Evaluate (IRE) triadic discourse pattern is a typical discourse pattern in classroom discussions [4], [11], [12]. In QAE/IRE, the classroom dialogue begins with a teacher asking/initiating a question to invite answers/response from students. When a student provides an answer, the teacher evaluates the answer. The process continues until students get the right answers. A defining feature of the QAE/IRE discourse pattern is that, more often than not, the teacher already has authoritative answers to the questions he raised. Such questions often do not initiate an inquiry process that invites dialogic arguments among all learning participants. It invites predefined short answers, which can be found or inferred from textbooks.

Then, what do students learn through a practice characterized by talking about ready-made science? Kelly and Crawford [9] maintain that it eventually leads to false belief about the nature of scientific knowledge. They argue that students generally believe that scientific knowledge is (1) generated by standard methodology, (2) created only by great scientists, and (3) discovered without controversies. It suggests that the discourse community in schools often foster a positivist epistemology—a belief that eventually relegates students as passive receivers of scientific knowledge.

Maintaining that a guiding discourse pattern for working scientists is doing science with language does not exclude the fact that scientists also talk about science contents. What differs scientific discourse from classroom discourse in talking about science is that scientists often talk about ready-made science with the intention to go beyond the information given [3] while it is often not the case in a typical classroom. Scientists talk about science with an aim to interrogate, rebuild, or even deconstruct the prevalent theories. Therefore, talking about ready-made science with an evaluative epistemology is also a way of doing science with language.

3. Designing Classroom Discourse as Doing Science with Language

3.1 *Guiding Design Objectives*

To help students do science with language, we articulate how students may thrive in a classroom ecology that situates learning in conducting scientific inquiry and making argumentation. In crafting this program, our goal is to engage students in the three design objectives that characterize scientific discourse—using language for scientific knowledge construction, using argumentation to validate knowledge construction, and using language to evaluative the constructed scientific knowledge.

3.2 Designing Students' Discourse Practice in Doing Science

Guided by the three design objectives, we draw from the stories of ancient alchemists to design the Legends of Alkhimia 3D role-playing game (referred to as LOA game) and a game-based learning curriculum (referred to as LOA curriculum). The LOA curriculum is an eight-session chemistry-learning program for secondary (middle school) science education in Singapore. The LOA game is the cornerstone where all curricular activities are structured.

In a typical LOA curricular unit, the program begins with students sharing their experience related to scientific inquiry, such as asking questions. Then they play a level of the LOA game as a team of four apprentices of a senior chemist. In game play, students encounter problematic situations, ask questions, propose hypotheses and conduct virtual experiments to solve the problem in game. Following game play, students analyze virtual data collected in game play and propose theories about the nature of in-game virtual substances via small group and whole class dialogic arguments. In the entire curriculum, students are situated in designed contexts where they need to use language to do science—constructing theories, making arguments and evaluating others' theories. The following describes in details how the design of LOA game and curriculum situates students in a learning context that requires doing science with language.

3.3 The Legends of Alkhimia Game

Role-playing in the LOA game as apprentices of a master chemist, students face six levels of game challenges in the virtual place of Alkhimia. Typically, a game challenge is designed to engage players in cycles of three Inquiry Actions. First, a player encounters a situation that can be overcome by conducting appropriate “virtual” experiments. He must identify the sources of the problems and hypothesize how he may tackle the challenges. Second, he conducts virtual experiments in the virtual lab in order to produce virtual substances (designed based on Earth substances) that may solve the problems. Third, he tests the lab generated virtual substances—and therefore his hypotheses—in the game challenges in order to investigate how they work. For example, in Level One of the LOA game, the players were attacked by three moderately reactive metallic monsters, which can be destroyed using cartridges with acid in the battlefield. Defeated by the monsters, players manage to retreat to the virtual lab where several lab functional units and apparatus are available for conducting experiments. The players’ experiments are guided by their hypotheses about how the monsters can be destroyed. After the experiments, players return to the battlefield to face the monsters until they successfully defeat them.

To design a context where players can do science with language, we position the game in an era where all Alkhimia substances have not been investigated and named. It situates players in a world similar to that of the ancient alchemists on Earth. Players must collect and identify suitable data from multiple resources in game, such as the procedure through which a virtual substance is produced and its effectiveness against virtual monsters in the battlefield, to interpret and construct knowledge about the Alkhimia substances.

3.4 The Legends of Alkhimia Curriculum

The three in-game Inquiry Actions comprise three key procedures in an inquiry cycle—asking questions, proposing hypotheses and conducting investigation. The after-game activities make it a full inquiry cycle by asking students to (1) analyze data and (2) synthesize findings. Following game-play, students organize themselves in their game-play groups to propose their theories about the properties of the virtual substances. They share their own in-game inquiry notebook and game log (log of virtual experiment and game play) with the group members in order to select the best notebook to present to the class. Students will also negotiate how the Alkhimia substances are classified and what names to be given to them. When doing this, students must also defend their claims by using the game log as evidence. As students present their hypotheses about the properties of the in-game substances, they make their hypotheses/claims visible to the whole class for evaluation in teacher-facilitated whole-class discussions.

In the QAE/IRE triadic discourse pattern, a teacher plays the role of content authority. In the Legends of Alkhimia curriculum, the teacher facilitates the discourse practice toward constructing knowledge with dialogic argument. She interprets (and invites other students to interpret) students’ performance (e.g. classification and naming of substances) and speech acts. He or she will also mediate discourse as a more or less equal voice. At times, the teacher questions students as a curious co-participant. At times, he or she assumes more control in guiding the direction of the arguments.

As closure to the session, students will vote, as a class, the best names for the substances. The teacher will also recap the knowledge constructed by the class as a way to help students understand the constructed nature of scientific knowledge. After the session, each student will complete tasks online on a wiki. They will write a narrative in the form of a diary entry about their personal experience in the game and their personal reflection upon their experience.

4. Conclusion

Guided by a design-based research approach [1], [2], we characterize the defining features of two science discourses—working scientists and students—to develop a design guideline for designing the LOA game and curriculum. The main purpose of our design is to provide a context where students are immersed in using language for doing science. In proposing and designing the LOA game-based learning program, we also acknowledge the limitations of our design in transforming current educational practices. As the belief guiding the design of the mainstream educational systems differs from ours, we expect pushback from the current system at multiple levels—administration, teacher education, pedagogy, and even the physical configuration of classrooms. Therefore, changing how students practice science discourse is but a beginning that must also initiate changes at different levels.

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