US-China Education Review B 6 (2011) 786-796
Earlier title: US-China Education Review, ISSN 1548-6613

Reconceptualizing Science Classroom Discourse Towards Doing Science Through a Game-Based Learning Program*

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There is a need for schools to engage students in constructing scientific theories like practicing scientists in order to excel in the 21st century knowledge economy. An approach to engage students in constructing scientific theories is to enculturate students in doing science with language, which differs from the mainstream classroom discourse—talking about science. In terms of doing science with language, young people use language to produce scientific knowledge like practicing scientists. When it comes to talking about science, students learn to master science knowledge constructed by scientists, eventually leading to a positivist epistemology and consumer identity. In this paper, we conceptualize an approach to design science classroom discourse toward doing science and instantiate the conceptualization with a game-based learning program. The result is eight two-hour sessions chemistry program that is revolved around a six-level role-playing computer game—the “Legends of Alkhimia”.

Keywords: science discourse, science education, game-based learning, design-based research, chemistry learning, inquiry-based learning, new literacies

Introduction

Viewing science learning as learning a body of expert-generated content knowledge is a prevalent learning practice in the 20th century science classroom (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Kelly & Crawford, 1997). Since mastering expert-generated content is viewed as a legitimate learning goal, educational systems are often conceptualized and designed to enact this belief. The compartmentalization of science learning into grade levels and subjects, the employment of direct instruction as a dominant teaching approach, the design of textbooks and blackboards and the employment of content-based assessments are all streamlined to effectively enact this learning belief.

For the most part of the 20th century, this belief about learning and corresponding educational systems performed efficiently in producing a reliable workforce for industrial societies. Though researchers also documented undesired, yet persistent side effects, such as the inability to apply learned content knowledge for problem-solving (Whitehead, 1929), the educational systems are mostly sufficient in serving the needs of the 20th century societies. After all, one who is capable of reading, writing and performing routinely assigned tasks

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*This research is supported by a grant from the National Research Foundation/Ministry of Education IDM (Interactive Digital Media) Projects in Singapore.

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is considered adequately literate in an industrial society. However, this traditional framing of learning and literacy are called into question when digital revolution and knowledge economy turns the globe into a flat world with exacerbating global competition (Friedman, 2005).

How might we respond to the challenges of learning coming from a societal paradigm shift from an industrial society to an information society? How does the paradigm shift change the ways literacies are viewed? What new literacy skills are essential for young people to excel in the global competition? Shaffer and Gee (2005) provided a compelling argument about the 21st century literacy—the ability to perform likes working scientists. The knowledge economy is dependent upon knowledge production and innovation. The abilities that make working scientists science knowledge producers, therefore, should be seen as a benchmark for 21st century literacies.

Though Shaffer and Gee (2005) articulated a plausible learning objective, helping students in schools to become knowledge producers similar to working scientists is challenging, especially when viewing from a perspective of community of practices (Lave & Wenger, 1991). Working scientists practice science considerably different from that in mainstream schools. It requires researchers and educators to redesign the learning environment that schools are agreeable to adapt without revamping schools and educational systems.

In this theoretical paper, we conceptualize science learning and propose a learning program intended to engage students in thinking and speaking more like working scientists. Our goal is to engage young people in doing science with language, which characterizes how scientists talk (Lemke, 1990; Roth, 2005). Specifically, doing science with language depicts how students utilize language to construct scientific knowledge. It differs from the mainstream talk in science classrooms—using language to understand prescribed concepts and memorize science contents. In instantiating our reconceptualization, we leveraged the affordances of game-based learning in designing players' experience (Squire, 2006) to design a learning program that employs a six-level role-playing game.

Discourse Practices in Communities of Practices

Discourse as a Lens Into Practices

Discourse, or language-in-use, is a major medium that shapes a community of practice (Gee, 2005). Through discourse practices, the members of a community enact their beliefs, identities and activities (Gee, 2005; Lemke, 1990; Roth, 2005). Therefore, examining discourse patterns that emerge in community practices provides a channel for understanding the nature of communities. We examine the discourse patterns in professional science communities and the mainstream science classrooms in order to understand how the two communities practice science differently in their discourses. Understanding the differences provides not only insights regarding how they practice science, but also frameworks or design heuristics that inform the reconceptualization and design of science learning in schools.

Discourse Patterns in the Communities of Working Scientists

The central belief guiding the practices of scientific communities is to construct scientific knowledge that can be used to make sense of the world (Driver et al., 1994; Sandoval & Milwood, 2005). Guided by this belief, the discourse practices in scientific communities have been developed towards building knowledge construction communities. A pattern pertinent to this discourse practice is doing science with language (Gee, 2004; Lemke, 1990; Roth, 2005). In doing science with language, scientists develop specialized language and approaches to conduct scientific researches. Lemke (1990) characterized this unique discourse pattern as talking science. When talking science, scientists utilizes language to facilitate their knowledge construction activities, such as observation, comparison, evaluation, hypothesis, generalization, design, discussion, etc.. In other words, scientific communities develop specialized ways of using language to help them conduct scientific research. The following aspects of doing science with language depict some of the salient features of this language action tool:

(1) Using language as a tool for scientific knowledge construction (Gee, 2004; Lemke, 1990; Roth, 2005). Central to this particular language tool is its function in serving scientific inquiry, which can be further delineated as language used for questioning, hypothesizing, investigating, evaluating, theorizing, etc.;

(2) Using argumentation as a tool for validating knowledge construction (Driver, Newton, & Osborne, 2000). Scientists use language not only in constructing knowledge, but also in examining the 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.

The epistemology underlying doing science with language is constructive (Driver et al., 1994) and evaluative (Kuhn, Cheney, & Weinstock, 2000). The language employed in doing science reflects an evaluative epistemology. Language that carries out an evaluative epistemology, such as developing hypothesis, examining evidence and looking at counter theories signals one’s epistemology about science.

By maintaining that a guiding discourse pattern for working scientists is doing science with language, we do not exclude other ways of using language for science, such as talking about science. In fact, working scientists also develop specialized language, such as technical terms to describe the products of their research results (Gee, 2004). Talking about the knowledge products or ready-made science is also a defining feature that can be said to be a common discourse pattern in working scientific communities. However, their ways of talking about ready-made science differ from classroom talk. Working scientists often talk about ready-made science with the intention of going beyond the given information. Therefore, they talk about ready-made science often with an aim to interrogate, rebuild or even deconstruct ready-made science. Therefore, talking about ready-made science with an evaluative epistemology should also be considered as a way of doing science with language.

Discourse Patterns in the Mainstream Science Classroom

In school communities, young people practice science as students. Ethnographic studies of classroom science practice (Bowen, 2005; Kelly & Crawford, 1997) suggested that their discourse practice unfolds distinctively different ways of practicing science. The prevalent discourse pattern in the mainstream science classrooms may be characterized as talking about science (Lemke, 1990; Gee, 2004). Talking about science means that students spend most of their time for classrooms, among peers, exams, talking about ready-made science without critically examining the processes through which the scientific theories are constructed. In most cases, they talk about scientific theoretical constructs as universal laws discovered by great scientists (Kelly & Crawford, 1997). For example, they may talk about the greenhouse effect and how it is related to global warming. The discussions usually focus on what has been discovered without considering the controversies among competing theories. When the discussions do go beyond textbook contents, they are usually more about applying the knowledge to reaffirm its applicability, as opposed to interrogating the construction of the knowledge. The purpose of talking about science, therefore, is to ensure that students have acquired conceptual understanding. The talk rarely positions scientific theories as human constructs that can be re-theorized in the presence of emerging evidence. Such a classroom discourse pattern eventually mystifies science as authoritative and out of the reach of most students (Driver et al., 1994; Kelly & Crawford, 1997; Kuhn, 2005; Lemke, 1990).

In mainstream classrooms where direct instruction is a norm, students often do not have much opportunity to enact science through discourse practices, such as dialogic arguments (Kuhn, 2005). When there is a discourse exchange, it often takes the form of simple questioning and answering between students and the teacher (Lemke, 1990), with the teacher providing one-sided answers that tend to reinforce science as the "unmitigated rhetoric of conclusions" (Schwab, 1962).

The QAE (question-answer-evaluate) or IRE (initiate-response-evaluate) triadic discourse pattern is one of the typical patterns in science classrooms (Cazden, 2001; Lemke, 1990; Mehan, 1979). In QAE/IRE, the classroom dialogue begins with a teacher asking/initiating a question to invite answers/responses from students. When a student provides an answer, the teacher evaluates it and the process will continue until the right answers are provided. 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 a question is raised not as a way to initiate an inquiry process characterized by dialogic arguments and evaluative epistemology. It invites predefined short answers, which often can be found or inferred from science textbooks.

Then, what do students learn through a practice characterized by talking about ready-made science without practicing science-in-the-making? In an ethnographic study that interrogates the norms of classroom discourse, Kelly and Crawford (1997) maintained that the typical classroom science discourse practices eventually lead to false belief about the nature of scientific knowledge. Students generally believe that scientific knowledge is: (1) generated by standard methodology; (2) created only by great scientists; and (3) discovered without controversies. Such a finding suggests that the discourse community fosters a positivist epistemology—a belief that eventually relegates students as consumers of science.

In maintaining the typical classroom discourse pattern as talking about ready-made science, we do not claim that students and teachers do not use language to do science at all. There are policy-makers, administrators, teachers and students who are making their best efforts to transform science learning towards doing science with language. Our goal here was to highlight a typical discourse pattern that emerges in the design of the science learning programs in the mainstream schools. From there, we examined how it is situated in the design of the classroom discourse community.

Situating Classroom Discourse Patterns in Design

The design of learning practices is guided by deep-rooted beliefs. Therefore, without interrogating the beliefs that shape the educational landscape, we often reproduce the same with newer technologies. Even worse than the pricier replacement of old technologies may come from unsettled teachers, confused students and disgruntled parents. In designing classroom discourse practices, we began with examining the beliefs guiding mainstream science classroom practices.

In science education, the beliefs pertaining to the nature of doing science guide classroom practices. The mainstream science curricula are designed based on the belief that science can be acquired by mastering scientific content knowledge (Driver et al., 1994; Gee, 2004). This belief permeates the entire learning environment through design. Technologies play a central role in realizing the belief. In the case of mainstream science classrooms, major technologies are designed to facilitate the effective transmission of scientific conclusions—knowledge generated by great scientists like Isaac Newton and Dmitri Mendeleev. Textbooks remain the most widely used technologies in the K-16 curricula (Sewall, 2002) in the digital age. Developed as a transmission technology, textbook is perhaps the most indispensable technology serving the educational systems around the world. Most textbooks employ an encyclopedic writing style, an effective way of summarizing ready-made science in an unambiguous fashion (Bierman, Massey, & Manduca, 2006). Coupled with the transmission technologies, direct instruction is often a preferred pedagogy in monitoring the transmission progress. To monitor the effectiveness of the learning results, standardized tests are installed to ensure that the entire educational system is aligned with its beliefs about science learning. As discussed earlier, this content mastery model of science learning was feasible in an industrial society. However, the tradeoffs in contracting science learning as learning scientific facts should not be ignored when we envision students as knowledge producers and innovators. In this simplification process, the procedures and processes through which scientific knowledge are constructed, such as experiments and observations, are often taken lightly, if not bypassed (Chinn & Malhorta, 2002). In many cases, scientific processes are introduced as a way of facilitating content mastery (Driver et al., 2000; Kelly & Crawford, 1997; Kuhn, 2005), instead of learning to inquire science.

Students' science practice is situated and distributed in this ubiquitous mediating structure that both organizes and constrains learning (McLuhan, 1964; Pea, 1993). The design of the learning environment affords content mastery, but inhibits other ways of learning at the same time. Furthermore, standardized assessments keep students' learning styles and teachers' pedagogies in check. Students who choose to learn science differently must also consider if doing so it will jeopardize their performances, which is often assessed based on content mastery instead of the ability to conduct scientific inquiries.

Teachers face the same structural constraints when they try to incorporate different learning approaches, such as scientific inquiry, in the content-driven educational paradigm. To enrich students' learning with alternative pedagogies, they often run the risk of losing their credibility from parents and supervisors, which is in many cases evaluated based on how well their students perform in standardized tests that assess content knowledge. In other words, the design of the learning environment establishes a learning ecology that not only favors talking about ready-made science, but also punishes other ways of learning (McLuhan, 1964; Postman, 1993).

Designing Classroom Discourse as Doing Science With Language

Guiding Design Heuristics

In the previous section, we articulated the discourse patterns that may help students perform as knowledge producers similar to working scientists. The key to this discourse pattern is to do science with language, such as making hypotheses with collected evidences. Even when students talk about science, there is a need to maintain the authenticity of evaluative epistemology, helping students understand that the scientific theories presented in textbooks are constructed by scientists in similar processes.

To help students do science with language, we articulate how students may thrive in a classroom ecology that situates students in doing science with language. Consistent with previous learning program design (White & Frederiksen, 2000), technologies will be designed to engage students in scientific inquiries instead of transmitting ready-made science more efficiently. To achieve the goals, we reverse engineer classroom science practice from a textbook-based ready-made science learning program to a science-in-the-making learning program. In crafting this program, we wish to engage students in doing science with the three aspects of scientific discourse mentioned earlier—using language as an action tool for constructing knowledge, performing dialogic argumentation and developing evaluative epistemology.

Designing Students' Discourse Practice With Game-Based Learning Approaches

The ancient alchemists who asked how base metals might be turned into gold inspire us to design a science-in-the-making process for discourse practice. To investigate how base metals may turn into gold, ancient alchemists came up with hypotheses, conducted experiments in order to test their hypotheses, interpreted data and constructed theories regarding the properties of substances. Alchemy provides an inquiry model that may engage students in inquiries similar to those conducted by ancient alchemists. To engage students in similar inquiry process, we leverage the affordances of 3D (three-dimensional space) role-playing computer games to design a learning program, through which students must use language to do science, such as hypothesizing, experimenting, interpreting, synthesizing and theorizing.

The "Legends of Alkhimia" curriculum is an eight-session chemistry-learning program for secondary (middle school) science education in Singapore. The "Legends of Alkhimia" game is the cornerstone based on which all curricular activities are structured. Through six levels of game challenges, students confront problematic situations that can be solved by conducting scientific inquiry both inside and outside of the game. In a typical session, the program begins with students sharing their personal experience related to the inquiry subject, such as their experience in asking important questions and finding answers on their own. Then, they play a level of the "Legends of Alkhimia" game as a team of four science apprentices. During game play, students encounter game challenges that can be solved through cycles of questioning, hypothesizing, experimenting and theorizing. Following game play, the teacher brings all students together to collaboratively interpret the phenomena in the game in order to consolidate findings and theories regarding the nature of virtual substances that appear in the game world. The following section delineates how we design students' discourses towards doing science with language with the "Legends of Alkhimia" game and curriculum.

The "Legends of Alkhimia" Game

Scientific inquiry is situated and distributed in the social and material context (Brown, Collins, & Duguid, 1989; Pea, 1993). The "Legends of Alkhimia" game provides the materials that mostly leverage a player's individual inquiry experience while the curricular activities socialize students' experience as collaborative scientific inquiries. The following describes how students' scientific inquiry is situated in the virtual game world Alkhimia.

Role-playing as junior scientists, students face game challenges one after another in Alkhimia. Typically, a game challenge is designed to enable students experience cycles of three steps. First, a player encounters a challenge (opening a gate made of unknown substances) that can be overcome only by conducting appropriate virtual experiments within the game. He must identify the sources of the problems and hypothesize how the problems may be solved. Second, the player executes his ideas in the in-game virtual lab in order to produce substances that may solve the problems. Third, the player tests the substances generated in the virtual lab—and therefore his hypotheses—in order to realize if his hypotheses work. These three steps are designed to be a complete inquiry cycle that will extend from the game to after-game activities. To tackle these challenges, students must propose hypotheses, conduct virtual experiments, test their lab products in the virtual fields (in the game), construct explanatory theories dialogically and collaboratively after game play (in class). This inquiry cycle will be repeated six times with six levels of game in the entire eight-session learning program.

For example, in level one of the "Legends of Alkhimia" game, the players were attacked by three moderately reactive metallic creatures, which can be destroyed using acid in the field. The game system does not inform players what they are. Facing this problematic situation, players are equipped with a gun and cartridges, which could be used as weapons against the metallic creatures. The cartridge, a mixture of sand and acid (which is unknown to the players), will jam their guns initially because of the sand in the cartridges. Defeated by the creatures, players manage to retreat to a virtual lab where several lab functional units and apparatus are available for conducting virtual experiments. The lab apparatus are all designed based on real lab apparatus so players may bring their prior knowledge into the game. If a player hypothesizes that their cartridges are jammed because of impurity in the cartridges, he may conduct experiments that enhance the purity of the cartridges, such as using two types of filters, separating funnel or the combination of a few lab functional units to purify the cartridges. The player can then bring the produced cartridges back to the field to see if his hypothesis and experiments work as predicted. In the game, players, by design, will fail in their initial test. Each failure provides players critical information about the challenge. A successful player must view his failure as a data collection process and modify his hypotheses accordingly in order to be successful in playing game meaningfully. Figure 1 is a screenshot of a virtual experiment in which a player tries to separate unknown substances from a green mixture.

Figure 1. Players conducting experiments in the "Legends of Alkhimia" game.

A key design decision that engages students to do science with language—by asking, hypothesizing, experimenting, investigating, testing and theorizing—is that players are situated in a virtual world where all virtual substances have not been investigated and named. It situates players in a world similar to that of the ancient alchemists. Players must collect and identify suitable data, acquired from multiple resources in game, such as the procedure through which a cartridge is produced and its effectiveness against monsters in the field, to interpret and construct knowledge about these substances. To make it more accessible to secondary students, we record players' game action in a "game log" which depicts the process through which each cartridge is produced, such as the lab apparatuses being used and its effectiveness in tackling the challenges. The game log can be seen as raw data and later developed into hypotheses and theories. Table 1 describes the activities in each game level and how each level is related to key chemistry concepts designed into the game.

Table 1

Major Game Challenges and Related Chemistry Concepts

Level	In-game challenges		Related ideas/concepts in the design
1	Lab	Separate mixtures (solid-liquid, solutions)	Strong and weak acids dissociate in water to different extents Separation of substances can be based on size of particles and boiling points Kinetic theory
	Field	Destroy metallic monsters	
2	Lab	Separate mixtures (solid-liquid, solutions)	Depending on the substances to be recovered and the properties of the substances, different separating techniques are used Collision theory
	Field	Destroy acid monsters	
3	Lab	Neutralize samples of acids and bases in the lab	Metals can be classified according to their reactivity Reactivity of metals affect the rate of reaction of metals with acids Properties of material affect uses of the material: Insoluble bases are used instead of soluble bases to neutralize acids
	Field	Neutralize contaminated cabbages in the farm	
4	Lab	Test effect of temperature on rate of reactions in lab	Substances may or may not react with other substances depending on whether heat is applied Properties of material affect uses of the material: Carbon dioxide is used in fire extinguishers; hydrogen is used in airships and as rocket fuel
	Field	Destroy acid monsters in both cold (mountain-top) and hot (underground) conditions	
5	Lab	Separate solutions, miscible and immiscible liquids	Depending on the substances to be recovered and the properties of the substances, different separating techniques are used Big ideas/concepts as levels of 1 and 2
	Field	Use liquids to destroy door made of metal of very low reactivity	
6	Lab	Synthesize notes taken of substances and reactions from previous levels	Big ideas/concepts as levels of 1-6
	Field	Select best metals for ammunition and armor Destroy super monster	

The "Legends of Alkhimia" Curriculum

While the "Legends of Alkhimia" game affords mostly individual cognitive inquiry experience, the curricular activities extend the individual inquiry to a collaborative experience in the classroom. Since the curricular activities are designed to ask students to theorize their findings while playing the game, it keeps students in the discourse games designed to foster dialogic arguments (Kuhn, 2005).

In session one, the "Legends of Alkhimia" curriculum begins with the orientation of the deep blue, a scientific institute based in the country of Bella on earth and in the town of Alkhimia in the virtual world. Students are recruited as junior scientists by the deep blue to undergo an eight-session training in order to become a more experienced young scientists. In the following six sessions (sessions two to seven), students, now junior scientists, will initiate their training in Bella, enter the virtual world of Alkhimia to tackle game challenges, and then come back to Bella on earth to synthesize their findings at Alkhimia. At session eight, junior scientists must present their research on an inquiry assignment in order to make a case for themselves as qualified young scientists.

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 with group members in order to select the best notebook to present to the class. In the process, students need to negotiate what counts as a good inquiry and bring these criteria into evaluating and selecting the best set of notes.

Students also negotiated how the substances are classified and what names to be given to them. When doing this, students must defend their claims by using the game log as evidence. As students have formulated their hypotheses about the nature of the in-game substances, they make their hypotheses/claims visible to the whole class. Each group will take turns to report on their in-game inquiry. Thereafter, this monologic argument turns into a dialogic argument among all students in the teacher-facilitated whole-class discussion.

In the QAE/IRE triadic discourse pattern, a teacher usually plays a leading role as content authority. In the "Legends of Alkhimia" curriculum, the teacher facilitates the discourse practice towards collaborative knowledge construction via dialogic argument. He/she interprets (and invites other students to interpret) students' performance (e.g., classification and naming of substances) and speech acts. He/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/she assumes more control in guiding the direction of the arguments.

As closure to the session, students will vote, as a class, for the best names of the substances. Assuming the role of a more experienced researcher, the teacher will also recap the knowledge constructed by the class as a way to help students consolidate their temporary conclusions. 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. Table 2 describes the major activities in each session of the "Legends of Alkhimia" curriculum.

Table 2

Learning Activities in the "Legends of Alkhimia" Curriculum

Session	Topic/learning outcome/activity	Game play
1	In-session: Deep blue company orientation Personal profile/forming teams	Not required
2	In-session: Inquiry focus: Question Out-of-session online discussion/research: Classes of substances (elements, mixtures, compounds, metals and non-metals)	Level 1 Separate solid-liquid mixtures Destroy metal monsters
3	In-session: Inquiry focus: Hypothesize Out-of-session online discussion/research: Classes of substances (solute, solvent and solution)	Level 2 Separate mixtures (solid-liquid, and solutions) Destroy acid monsters
4	In-session: Inquiry focus: Investigate Out-of-session online discussion/research: Common reactions of acids	Level 3 Neutralize samples of acids and bases in the lab Neutralize contaminated cabbages in the farm
5	In-session: Inquiry focus: Analyze Out-of-session online discussion/research: Classes of metals (according to reactivity) Factors of rate of reactions (reactivity of metal and temperature)	Level 4 Test effect of temperature on rate of reactions in lab Destroy acid monsters in both cold and hot conditions
6	In-session: Media literacy Getting started on final assignment Out-of-session online discussion/research: Mixtures of liquids (solutions, miscible and immiscible liquids)	Level 5 Separate solutions, miscible and immiscible liquids Use liquids to destroy door made of metal of very low reactivity
7	In-session: Inquiry focus: synthesize Out-of-session online discussion/research Preparation for final assignment	Level 6 Synthesize notes Select best metals for ammunition and armor Destroy super monster
8	Group presentation of final project task	Not required

Conclusions

Designing Science Classroom Discourse Experience With Game-Based Learning

In this paper, we synthesize the defining features of two science discourses: working scientists and students. The synthesis identifies the gap that we need to bridge if the goal of science education is to foster new science literacy—the ability to do science with language—for the challenges of 21st century knowledge economy (Shaffer & Gee, 2005). Based on the synthesis, we also conceptualized how we may foster doing science with language and propose a design heuristic—using language as an action tool for constructing knowledge, performing dialogic argumentation and developing evaluative epistemology. Following the design heuristic, we designed students' discourse experience toward doing science by situating them in a game-based learning program. In the "Legends of Alkhimia" game and curriculum, students role-play as apprentice chemists to conduct scientific inquiries. The learning program engages students in using language to perform scientific inquiries. In particular, we designed their discourse experience by situating their science talks in dialogic arguments through game-play and curricular activities.

Situating Our Design in Design-Based Research and in Educational Ecology

Oriented by the design-based research approaches (Barab & Squire, 2004; Brown, 1992; diSessa & Cobb, 2004) to engineer the learning context, we developed a design heuristic similar to the "frameworks for action" proposed by diSessa and Cobb (2004). We maintained that this design heuristic may also serve as a general design guideline for other game-based learning programs and could be useful for other technology-enhanced learning curricula, when the proposed learning objective is to help students do science with language.

In proposing and designing the "Legends of Alkhimia" game-based learning program, we also acknowledge the challenges of our design in transforming educational practices in the mainstream schools. As the belief guiding the design of the mainstream educational systems differs from ours, we expect pushback from the current system at multiple levels—policy, 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 cultural and ecological change in the future.

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