Chapter 16
Learning Chemistry Performatively: Epistemological and Pedagogical Bases of Design-for-Learning with Computer and Video Games

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16.1 Introduction

Typical textbooks in chemistry present the field as a fait accompli represented by a body of "proven" facts. For example, a textbook (Heyworth 2002) used in the lower secondary science curriculum in Singapore makes the following claims:

- Atoms are so small that nobody has ever seen a single atom. But *scientists are certain* they exist. (p. 26, italics added)
- *Scientists have discovered* that atoms are made up of three smaller kinds of particles—protons, neutrons and electrons. (p. 32, italics added)
- *It's a Fact!*
  In 1915, Ernest Rutherford fired particles containing protons at some nitrogen gas (atoms of proton number 7). Protons entered the nuclei of the nitrogen atoms and changed them into oxygen atoms (of proton number 8). (Sidebar entry, p. 35, italics added)

The examples above are indicative of the common rhetoric of science that revolves around assertions of fact, scientific discovery, and certainty. Students with the capacity for critical thinking would invariably wonder *why* scientists are so certain of the existence of atoms if no one has ever had the opportunity to see an atom. The textbook author provides no explanation for his existence claim. Student questioning is also not invited. The second example makes use of authorial privilege to assert a claim that atoms, although never ever seen, are composed of protons, neutrons, and electrons. But do scientists merely *discover* this "fact," or is the atom merely a model invented by scientists to help them explain and

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predict chemical phenomena and may not exist at all? The final example appeals to the textbook writer's authority as subject expert to assert a factual claim concerning what Ernest Rutherford succeeded in doing. Why would a thinking student believe such a claim? How would a student even begin to conceive of firing particles containing protons into nitrogen gas? Given the extensive gaps in explanation and credibility, it is hardly surprising that students' mastery of chemistry "facts" through memorization is associated with minimal understanding of the domain and of chemistry processes.

Overall, the presentation style reflected in the textbook is dogmatic, and it does not entertain any form of interrogation or challenge by the student reader. The underlying message is clear: "Do not question; just accept what you are told." In a classroom where the teaching of chemistry is conducted in a traditional manner, teachers further reinforce the image of science as a form of proven dogma. Teachers verbalize and expound the facts. The students' role is to memorize and profess the "right facts." If not, they risk being penalized in their chemistry assessments. Regrettably, students have little, if any, agency to engage in scientific inquiry and to construct their personal understanding of the field. An emphasis on predetermined "knowledge" coupled with the execution of laboratory experiments designed mainly to confirm predetermined "findings" can lead to students leaving school with a grave misunderstanding of the nature of science. Students will not realize that scientists actually require imagination and creativity to invent explanations and models to explain phenomena, and that scientific knowledge is tentative, subject to change, and can never be absolutely proven (Lederman et al. 2002; Schwartz and Lederman 2002). They will also be surprised when they find out that there is competition between rival theories and among "camps" of scientists, that experiment data can be interpreted in more than one way depending on what theory one subscribes to, and that theories can contradict each other (Niaz 2001). These issues are seldom brought up or discussed in class. In general, then, students are not provided with access to authentic science education (Roth 1995). Neither are they helped to understand that engagement in the practice of doing science is the human activity that *creates* knowledge as an ongoing social process of constructing reality (Berger and Luckmann 1966; Knorr-Cetina 1999). The lack of opportunities to directly engage in the practice of doing science lead to outcomes that tend to be wanting: students fail to develop critical problem-solving skills required for conducting scientific investigations, they lack the capacity to interrogate the quality of evidence, and they do not imbibe the dispositions and values that undergird the practice of science. In short, science "knowledge" is mastered at the expense of developing scientific literacy (Murcia 2009). Unsurprisingly, we have witnessed widespread declining interest and participation in compulsory science education that extends beyond school.

In the next section of the chapter, we first share a praxiological framework for human learning that allows us to ground our design-for-learning on the theoretical construct of performance. We then provide readers with a description of what it is like to play level 1 of the game "Legends of Alkhimia." Using the game as a reference point, we next explicate the epistemological and pedagogical bases for the design of a game-based learning curriculum to help students imbibe the thinking, values, and dispositions of professional chemists. The next section considers some challenges of enacting a science inquiry curriculum based on a performance approach to game-based learning, that is, a performance pedagogy. The chapter concludes by summarizing a set of issues that teachers can consider to facilitate the process of change toward adopting a performance pedagogy.

16.2 Praxiological Framework for Studying Human Learning

In constructing the Alkhimia learning environment, our approach to designing the learning process is based on a praxiological framework for studying human learning that is inspired by Collen (2003) who proposed a philosophical foundation that undergirds a general methodology for human systems inquiry. In essence, Collen argues that any comprehensive attempt to study human systems and behavior must subsume three fundamental ideas from Greek philosophy, namely, *ontos*, *logos*, and *praxis*. Together, they yield a praxiology for human inquiry, including inquiry into human learning. Figure 16.1 depicts our appropriation and adaptation of Collen's original idea. This framework allows us to construct an understanding of game-based learning from a process-relational point of view (Chee 2010a; Mesle 2008) that emphasizes the importance of *knowing* through enaction rather than *knowledge* as subject content, whether derived from textbooks, the Internet, or elsewhere. A process-relational approach to understanding human learning foregrounds human *performance*, a term drawn from performance theory (Bell 2008; Carlson 2004) and performance studies (Schechner 2006), and constitutes an onto-epistemological shift to performativity (Barad 2003).

In our design-for-learning with respect to the Alkhimia chemistry curriculum, we deliberately chose to position learning as a form of engagement in human *inquiry* (Dewey 1916/1980; Postman 1995; Postman and Weingartner 1969). We use the term design-for-learning to emphasize the design of an extended learning process based on student engagement in inquiry in contrast to widespread approaches that focus on didactic teaching of subject content. Our praxiological framework allows us to frame learning in terms of human inquiry located in situated contexts. Collen proposed three components of the framework—*ontos*, *logos*, and *praxis*—and we have located the human learner at the center of the interwoven interactions and interdependencies between these three components. *Ontos*, or ontology, is the study of human being, human existence, and of what is. *Logos*, referring to epistemology, is the study of human knowing, what can be known, and what constitutes human knowledge. *Praxis*, or praxiology, is the study of action, the practices of human beings, and of what we (as humans) do. To understand human learning authentically and in all its rich complexity, we deem it vital that learning be studied in the context of humans engaged in situated action, including participation in speech acts and discursive practices that accompany everyday actions (Austin 1975; Bruner 1990; Clancey 1997; Dewey 1938; Gergen 1999). In taking this position, we explicitly

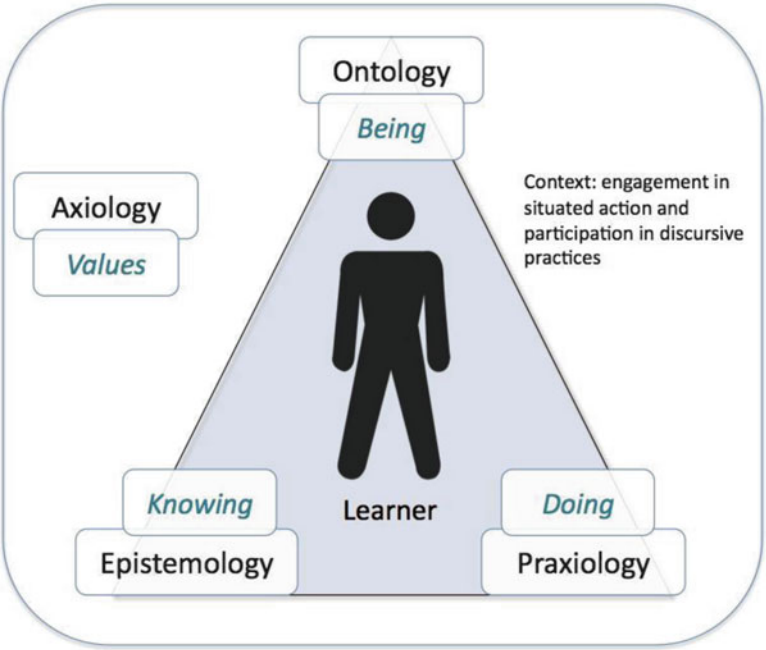

Fig. 16.1 Praxiological framework for studying human learning

reject learning outcomes where students can only talk *about* chemistry, without the ability to engage in the practice of chemistry. The framework in Fig. 16.1 emphasizes that human *knowing* is inseparable from human *doing* (Dewey 1916/1980). But, more than that, it also insists that human knowing and doing are deeply and inextricably intertwined with human *being* (Heidegger 1953/1996). The three elements may be conceived as an interwoven braid whose strength derives from the tight coupling between the components. The framework would not be complete, however, without the addition of a fourth component—values—because knowing, doing, and being are necessarily embedded within a larger sociocultural context of axiology, the study of human *values*. As Ferré (1996, 1998) and Putnam (2002) have argued, knowing, doing, and being are inherently value-laden activities. Humans make basic value distinctions related to all processes and outcomes of learning. These distinctions guide their learning actions toward outcomes that create positive value.

The praxiological framework for studying human learning establishes the foundation for understanding learning in terms of performance, as previously indicated. Central to the idea of performance is engagement in patterned behavior: the doing and redoing of certain identifiable activities, such as the way we present ourselves in everyday life (Goffman 1959). However, a ritualized pattern of behavior constitutes a performance only if there is a self-consciousness, on the part of the person or agent, of the doing and redoing of a pattern of activity. This self-consciousness gives rise to a double consciousness: a person's self-awareness of an actual behavior being enacted that is compared with an ideal intended behavior. Thus, a double consciousness allows the development of reflexivity and the ability of a learner to hold her own actions and behaviors up to personal scrutiny and interrogation (Carlson 2004). This reflexive interrogatory capacity allows the learner to renegotiate the status quo. As performance, learners can then reconstruct and redefine the kind of person they wish to be in relation to the values that they choose to uphold. This process of self-construction is ongoing, and it constitutes the person's trajectory of learning.

Being grounded in part on situated action, our praxiological framework finds resonance with Lave and Wenger's (1991) articulation of situated learning and with situativity theory in general (Barab and Duffy 2000). In the context of game-based learning, our approach, emphasizing embodiment, embeddedness, and experience (Chee 2007), also finds resonance with the work of Barab et al. (2007) with respect to learning with situationally embodied curriculum to achieve transformational play (Barab et al. 2010b). However, there is one critical difference. In adopting a process-relational approach based on process philosophy (Rescher 1996; Whitehead 1978), we hold that there is an inescapable interdependence between epistemology and ontology, giving rise therefore to onto-epistemology as suggested by Barad (2003, 2007). This positioning contrasts with that adopted in classical western philosophy, and apparently adopted by Schuh and Barab (2008), that positions ontology and epistemology independently: "ontology refers to 'what exists' while epistemology is concerned with 'how we come to know about' what exists" (p. 70). The classical positioning assumes that the world can be known objectively. This positioning has been shown to be deeply problematic (Dewey and Bentley 1949; Gergen 1999; Rorty 1979).

Barab and Duffy (2000) make the following claims: "Knowing about refers to an activity—not a thing; knowing about is always contextualized—not abstract; knowing about is reciprocally constructed within the individual-environment interaction—not objectively defined or subjectively created; and knowing about is a functional stance on the interaction—not a 'truth'" (p. 28). We argue that the first three references to "knowing about" are misplaced: they actually refer to "knowing" (as depicted in Fig. 16.1). However, the fourth reference to "knowing about" is appropriate. Furthermore, such "knowing about" is brought forth through language, as part of social participation in discursive practice (Coulter and Sharrock 2007). Failure to distinguish between "knowing" and "knowing about" can readily lead to an unduly high valuation placed on knowledge products: the "content" of knowing about. Thus, while Barab et al. (2010a) foreground intentionality, legitimacy, and consequentiality in transformational play, the focus of investigation is on teaching water quality concepts and using multiuser virtual worlds to support academic content learning. They report their findings in the following terms: "students were clearly engaged, participated in rich scientific discourse, submitted quality work, and learned science content" (Barab et al. 2010c, p. 387). In contrast, the praxiological framework seeks to achieve student learning outcomes defined in terms of an intertwined knowing–doing–being, where articulating conceptual claims constitutes a form of human knowledge representation (Clancey 1997) embedded in discursive practice. Such knowledge representations are always derivative and an outcome of the enactive process of knowing. In short, learning does not begin with knowledge (representations) but rather produces it. The goal of learning, therefore, is to be (a certain kind of person) with a distinct identity through performance. It is not to learn about content as such.

16.3 Learning with the Game "Legends of Alkhimia"

The game "Legends of Alkhimia" (LoA) was designed and developed by our research team at the Learning Sciences Lab, National Institute of Education, to serve as the technology-mediated component of a broader environment for learning chemistry by inquiry in lower secondary school. The learning environment includes not only the game but also associated curricula materials for in-class use that provide the activity structure for student learning activities accompanying game play. The game and materials together constitute the Alkhimia learning program. At the time of writing, the game comprises a six-level multiplayer game that supports four concurrent players. LoA is played over a local area network, typically in a computer laboratory in school. It has been developed to run on PCs.

The game begins in level 1 with a scenario where the four student players crash-land in the vicinity of the ancient town of Alkhimia. While exploring their environs, they are suddenly set upon by a group of fireball-hurling monsters that emerge from a nearby ravine. The players try to repel the monsters with the weapons they are carrying. These weapons, a form of gun, can shoot ammunition drawn from cartridges attached to the weapons. The players find that their weapons are not very effective against the monsters. Furthermore, their weapons frequently jam, making it even more difficult to destroy the monsters (see Fig. 16.2). After a short but furious battle, the monsters retreat into the ravine, leaving the players wondering about the composition of the ammunition in their cartridges and why the ammunition was ineffective in destroying the monsters. This situation establishes context for student engagement in inquiry.

The students receive an instruction from their master, Aurus, via an in-game communication center. He says, "It seems that the mixture you used was not strong enough to destroy the monsters. This could be due to impurities. Proceed to your lab benches to perform separation techniques on the mixture to form new cartridges." Being the first level of the game, this dialog serves to scaffold users with regard to what they might do to begin to solve the problem that they face. The students proceed to their respective virtual lab benches and perform the separation techniques within the game that each thinks will work best. (It should be noted here that the virtual lab bench is implemented with a special software tool that embeds a two-dimensional user interface into a three-dimensional game environment. Consequently, the user is not visible when the lab bench interface is displayed.) Each student chooses what he or she believes is the appropriate purified substance

Fig. 16.2 Players unsuccessfully fending off a monster attack in level 1

to use as ammunition the next time they chance upon the monsters, and they load their cartridge with the chosen substance.

Unknown to the players (but known to us as the designers of the game), the original substance comprises a mixture of acid and sand. A separating funnel (shown in Fig. 16.3) is thus not an effective apparatus for separating the original mixture as this apparatus works only for immiscible liquids. If a player uses the coarse filter paper (item at the top in the apparatus panel on the left), she will obtain two derivative substances, and she can choose to load her weapon cartridge with one of the substances. When the players encounter the monsters a second time in level 1 of the game, they will find that they are no better off than before. If a player uses the separating funnel, the mixture of sand and acid will flow straight through the funnel; hence, their experience in trying to ward off the monsters will be the same as before. If a player uses the substance in the beaker that was derived from mixture separation with the coarse filter paper, she will find that her ammunition is more effective than previously, but her weapon still jams occasionally. However, if the player uses the substance collected in the filter paper as her ammunition (sand), she would find her weapon jamming even more frequently than before. In addition, she will find that her ammunition is largely, but not totally, ineffective against the monster. It is only when a student uses the fine filter paper and she chooses the filtered substance in the beaker as her ammunition that she will experience the greatest success in repelling the attacking monsters (as indicated by the on-screen hit points). In this way, the

Fig. 16.3 A player performing a chemistry separation technique at the laboratory bench

game space allows students to experiment with quite different solution paths and to put different problem-solving solutions to the test in the second battle with the monsters. Thus, the game allows divergent solution paths, and students are not all required to do the same thing at the same time. This design allows for greater personal agency in game play and consequent learning. The vital pedagogical principle in operation here is that the design-for-learning must support meaning making in a relational way. By experimenting with different alternative solutions, some of which work and others do not, students begin to understand why some actions work better than others and why other actions do not work at all. In short, the designed learning experience gives them the opportunity to cite evidence and to provide justifications for what they believe is "right" (i.e., it is a solution that solves the problem) because they have personally experienced how other alternatives fail to solve the problem. Hence, what is "right" is "right" only in relation to all that is "wrong": an important idea drawn from structuralism (Klages 2006).

Assuming that students execute different methods of mixture separation and based on the fact that the associated consequences of those actions will manifest differently in the second encounter with the monsters, the question that students will invariably ask is *why*? For example, why was Peter able to kill the monsters when I was not able to do so?

The cognitive dissonance generated by students' game play transitions into a classroom space of dialogic learning where, under the guidance of a teacher, students learn with one another to construct answers to their pressing questions. This form of dialogic learning can take place first at the student group level, then at the whole class level. In this process, students engage in making sense of their collective game experience. Depending on the time available and on teacher preference, it is also possible to go directly into whole class discussion. In our research experience, we have had occasion to use both. When using the latter arrangement, we place students belonging to the same game play together so that they can speak from a common perspective based on a common game play experience. Students reason to establish what different ammunition effects were observed and then work to identify the causal chain of actions that led to the observed effects. This process requires systematic reasoning that parallels the cycle of scientific inquiry involving questioning, hypothesizing, testing, analyzing, modeling, and evaluating.

As students continue playing "Legends of Alkhimia," the chemistry involved becomes increasingly complex. Like the apprentice scientists that the game positions them to be, they are *required* to develop their own classifications of the substances that they encounter in the game world. They do not experience the world as a prelabeled and a preconfigured place. This deliberate design inducts students into an authentic practice of science making by requiring them to *construct* functional and concise representations and organizations of knowledge. Drawing upon the knowledge constructions of different student groups, the teacher helps students to make critical evaluations about the constructions proposed by different groups. In this manner, students can begin to understand that the construction of scientific knowledge is a social enterprise based on a set of values that esteem explanations that are simple, parsimonious, and generalizable. Students can thus learn to imbibe the values, dispositions, and beliefs that undergird the practice of science making. From the perspective of learning design, we anticipate that learning chemistry in this manner will yield rather different outcomes compared to traditional emphases on content mastery. Given the limits on chapter length and the fact that the focus of this chapter is on design-for-learning, we have deliberately excluded rigorous reporting of empirical findings. Such results can be found in separate publications related to this research project.

16.4 Epistemological Basis of the Learning Design

The epistemological basis of learning with the Alkhimia learning environment is depicted in Fig. 16.4. It shows our performance–play–dialog (PPD) model of game-based learning design (Chee 2010b). This model instantiates a *performance epistemology*. It views knowledge as constituted in action, rather than existing a priori to action, and performance as the activity that allows students to develop competence in the field they are trying to master. By engaging in game play accompanied by speech acts in the form of dialogic conversations (Alexander 2004, 2008; Lemke 1990) that help to make sense of what took place in the game world, students manifest their understanding of chemistry phenomena in the game world of Alkhimia by

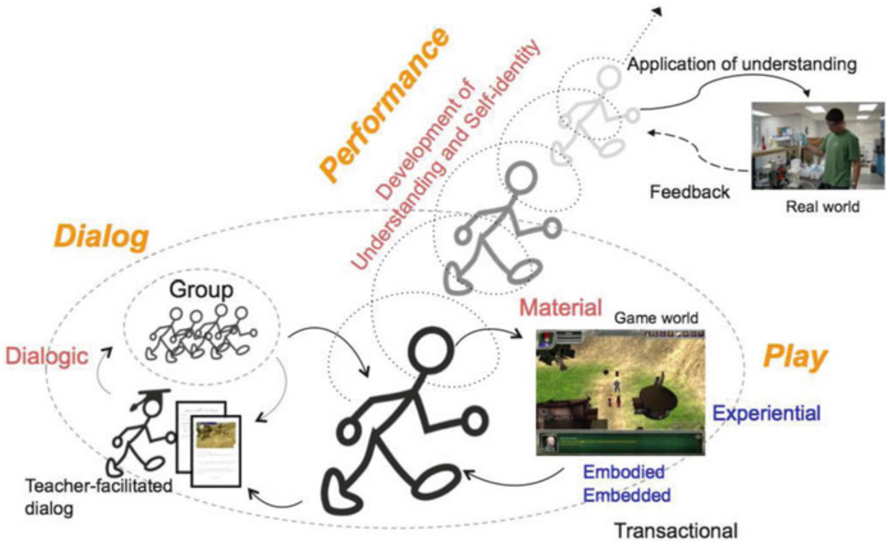

Fig. 16.4 The performance–play–dialog model of game-based learning design

performing (by word and deed) the actions that lead to successful in-game and out-of-game outcomes. Game play (depicted in the lower right corner of Fig. 16.4) takes place in the virtual world of the LoA game; the learning experience is *embodied* through the student's in-game avatar, *embedded* in the game world, and richly *experiential* in nature (Chee 2007).

It is necessary, however, for students to step out of the world of real-time game play and into a dialogic space of conversation where different ideas and viewpoints, or "voices," can interact with one another (Bakhtin 1981). From the Bakhtinian perspective of dialogicality, a voice refers to a "speaking personality." Utterances come into existence through being produced by a voice. As Clark and Holquist (1984) explain: "An utterance, spoken or written, is always expressed from a point of view, which for Bakhtin is a process rather than a location. Utterance is an activity that enacts differences in values." Dialog is thus an activity that creates a space for different student ideas and values to collide and interact with one another. The dialogic process (depicted in the lower left corner of Fig. 16.4) is facilitated by a teacher within a broader context of structured post-game play activities that scaffold students' meaning-making efforts. By engaging in this learning process, students come to understand chemistry performatively.

As shown in Fig. 16.4, as students engage in multiple levels of game play, they iterate over the play–dialog cycle that places them on a forward trajectory of developing competence through performance. Based on the model, they are envisaged to develop a performative capacity to think, talk, and act increasingly like professional chemists. This trajectory of the learning process, projected forward into time, is depicted by images of the student that become more faint as they move upward in Fig. 16.4. Learning in this manner operationalizes the dialectical interplay between first-person learning by doing and third-person learning by thinking/reflection that is key to Dewey's epistemology of learning by doing. In addition, performative learning is characterized by the gradual development of a self-identity that becomes a member of a professional practice community related to the domain, in this context, chemistry. This conception of learning is consistent with Thomas and Brown's (2007) call for student learning to shift away from "learning about" to "learning to be." As an approach to learning that places identity development as a key target outcome, the development of the student's professional identity constitutes a trajectory of becoming (Rogers 1961, 1980). Learning can thus be conceived of as a journey entailing becoming a certain kind of professional person, grounded in a community of practice.

16.5 Pedagogical Basis of the Learning Design

In striving for a chemistry learning environment that can support authentic, disciplinary learning, we have taken professional practice as a basic reference point for our pedagogical method. We seek to foster a form of learning that will enable students to begin to think, feel, and act like professional chemists. Our first level of theoretical reference, therefore, in designing the Alkhimia learning environment, is to the work of Bourdieu (1977, 1998) and to his theory of practice. As a social theorist, Bourdieu wrote extensively about social structures in relation to everyday human practices. A key concept in Bourdieu's discourse of practice is that of *habitus*, which expresses the way in which individuals "become themselves" through the development of attitudes and dispositions related to a professional field on the one hand and the ways in which individuals engage in everyday practices of the field on the other. The notion of habitus mirrors the concept of practical reason (also referred to as practical sense) that refers to a person's ability to understand and negotiate positions within the sites of cultural practice that are comparable to a sportsperson's "feel" for the game (Calhoun 2003). It should be evident from the foregoing that this orientation is praxiological. It is altogether situated in practice and focused on the enaction of behaviors that signify the values associated with a practice. It seeks to help students develop the vocabulary in use, the discourses, and the practices of a professional community, such as that of a scientific community. In short, it helps students to experience what *being* a chemist is like: an orientation that is ontological (see Fig. 16.1).

There is a second level of theoretical reference for our pedagogical design. This level is that of designing for students to participate in scientific inquiry. Like authentic scientists, students engage in "world construction" and meaning-making processes to construct their personal, and justifiable, understanding of the chemistry-related regularities that operate in the game world of "Legends of Alkhimia." The scientific inquiry process involves constructing pertinent questions for inquiry, framing candidate hypotheses that address the questions, engaging in empirical investigations to test the hypotheses, analyzing the data collected from the investigations, constructing an explanatory model of the experience phenomena, and evaluating the robustness of the model.

Fig. 16.5 Class activity of proposing names for game substances as part of the inquiry process

To illustrate one aspect of authentic engagement in scientific inquiry, we draw upon our first in-class enaction of the Alkhimia curriculum in a secondary school in Singapore to provide a concrete example. The participants in our research were 13-year-old students completing the chemistry portion of a general science curriculum that also included physics and biology. As part of our learning design, we asked students to make sense of the nature of in-game chemical substances that they encountered while playing the game. In the out-of-game classroom context, the teacher put up illustrations of the in-game substances introduced in level 1 of the game and invited students to propose suitable names for these substances. Figure 16.5 illustrates this activity in the classroom. It shows how five student groups suggested what they felt would be suitable names for the two substances they encountered in level 1: substance A, a green liquid, and substance B, composed of brown solid particles. As part of the learning process, students were asked to think about the properties of the substances and to provide justifications for why the name they proposed would constitute a "good" name. By facilitating an interrogation of what might constitute a "good" and hence suitable name, the teacher helped students to consider the experienced properties of the substances while playing the game and to relate this experience to naming norms within a scientific community. The latter activity is inherently value-laden because what constitutes a "good" name will vary from one professional community to another. Students were asked to vote on a preferred name so that the game substances could be referred to with unique names when they were encountered again in subsequent levels of the game. Students showed a strong tendency to name the substances based on perceived surface attributes of the substances. As is evident from Fig. 16.5, the names that were agreed on were "squishy liquid" and "dust."

Returning to the sociology of Bourdieu, our learning design is intended to help students to be reflexive about their own learning and to be critical in interrogating assumptions and biases that may shape the construction of their personal understanding. In this way, students are encouraged to practice epistemological vigilance, so that any social and cultural biases in their thinking can be exposed, queried, and discussed.

In summary, our design-for-learning seeks to address all four aspects of the general framework shown in Fig. 16.1: knowing, doing, being, and values. Student learning is conceived of as knowing that arises from doing within the broader context of being and learning to be, that is, becoming. All of this takes place against the background of a value system associated with the professional community of practice in question.

16.6 Challenges in Enacting Performance Pedagogy

Schoolteachers are faced with significant challenges when they consider the adoption of modes of teaching and learning implied in our pedagogy of game-based learning grounded on the construct of performance. Based on our experience to date working with teachers attempting to enact the Alkhimia curriculum for the first time, we found that they need to adopt a different mind with respect to teaching and learning because our pedagogy embeds deep epistemic change. Adopting this different mind-set, in effect, requires crossing a boundary into a new mode of teaching practice that is based on quite different epistemic assumptions.

We outline below the kinds of challenges that teachers face when contemplating adoption of a performance pedagogy in game-based learning. The distillation of these challenges arises from the conversations that we have had with teachers from two schools collaborating with us to enact the Alkhimia curriculum in their chemistry classes. By identifying the challenges explicitly, we hope that teachers not familiar with the pedagogy can better equip themselves to address the issues they will likely face to successfully enact the pedagogy.

16.6.1 Learning Outcomes and Epistemology

Traditional ways of teaching lower secondary school chemistry focus on students' mastery of content that arise from didactic teaching on the part of the teacher. We have argued that students' learning outcomes associated with this mode of teaching are weak because students have no opportunity to engage in the practices of doing science and constructing meaning in science. A performance epistemology values learning outcomes that enable students to enact authentic practices related to the doing of science as part of a broader goal of learning as being and becoming. This orientation represents a fundamental change in student learning goals toward identity development and professional practice. It is based on an epistemology of learning by doing rather than learning by being told.

16.6.2 Curriculum and Assessment

Conventional curricula goals and forms of assessment place great emphasis on students' mastery of subject content. Teachers are concerned that the adoption of game-based learning should not harm traditional content mastery given the same number of teaching hours. While this outcome may be desirable from a pragmatic perspective, it is not likely to hold in practice. Student mastery is likely to correlate highly with what a pedagogy seeks to promote. Thus, teaching for content mastery will lead to student excellence in content mastery, while teaching for performative outcomes will lead to student excellence in performative outcomes.

Teachers are also concerned about modes of student assessment and conforming to standard tests across a class level in school. The modes of student assessment need to be broadened to encompass more qualitative and rubric-based assessments given that outcomes are no longer evaluated purely in terms of getting the answers to standard questions right or wrong.

16.6.3 Concerns Relating to Student Prior Knowledge

Many teachers voice the fear that students will not know how to play the game successfully if they are not first taught the facts of the subject domain. This challenge reflects the difficulty that teachers face in recognizing that from a learning-by-doing perspective, competence is achieved only with performance. That is, students gain performance mastery in the domain through what they do. Distilling the knowledge products of learning is merely a by-product of learning by doing. The promotion of learning by doing does not take place in lieu of learning content. Rather, the latter is ancillary to the former.

16.6.4 School Logistics

The structure of student learning in schools is organized in terms of discrete blocks of time that range from about 35 to 60 min. Enacting a game-based learning curriculum typically requires blocks of approximately 120 min in order for game play and dialogic interaction and reflection to take place without feeling rushed. It is necessary, therefore, for schools to make special arrangements with respect to timetabling in order for a game-based learning curriculum to be enacted.

16.6.5 Sustaining Innovation

Game-based learning, as a pedagogical innovation, takes place within the cultural space of schooling. Our experience working with teachers across multiple schools strongly suggests that schools are inherently culturally bound spaces that are largely resistant to change. As stable systems, school practices have an inherent tendency toward self-perpetuation. Given that game-based learning requires change at a deep, epistemic level, there is often no assurance that a teacher who adopts an innovation will continue with it in future. This challenge is the outcome of deep tensions, and it is not easily resolved because the tension is systemic in nature.

16.7 Conclusion

In this chapter, we have articulated our conception of how lower secondary school chemistry can be enacted with game-based learning. We have argued that traditional ways of teaching chemistry, based on information dissemination and the assertion of scientific truth claims, are weak because this mode of teaching fails to deliver performative learning outcomes on the part of students. In lieu of traditional pedagogy, we have argued, based on a praxiological framework for studying human learning, that learning must address ontological, epistemological, praxiological, and axiological dimensions. Game-based learning, as we have constructed it, allows us to reconceive learning in a way that incorporates the processes of knowing, doing, being, and valuing, processes that we view as vital to an authentic approach to learning.

We elaborated on the epistemological and pedagogical bases of our design-for-learning and explained how learning in the Alkhimia learning environment proceeds. At the time of writing, two curriculum interventions, conducted in separate Singapore schools, have recently been completed. The findings from the empirical work in the classroom will be published elsewhere in due course. We also set out some of the known challenges to boundary crossing facing teachers contemplating the adoption of game-based learning as performance. The distillation of challenges arose from conversations that we had with teachers collaborating with us on the Alkhimia research project.

To conclude, we hope that this chapter helps to inform readers about the vision and opportunities for enhancing pedagogy through a performance approach to game-based learning. We also hope to alert teachers to challenges they may face in adopting this pedagogical innovation.

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