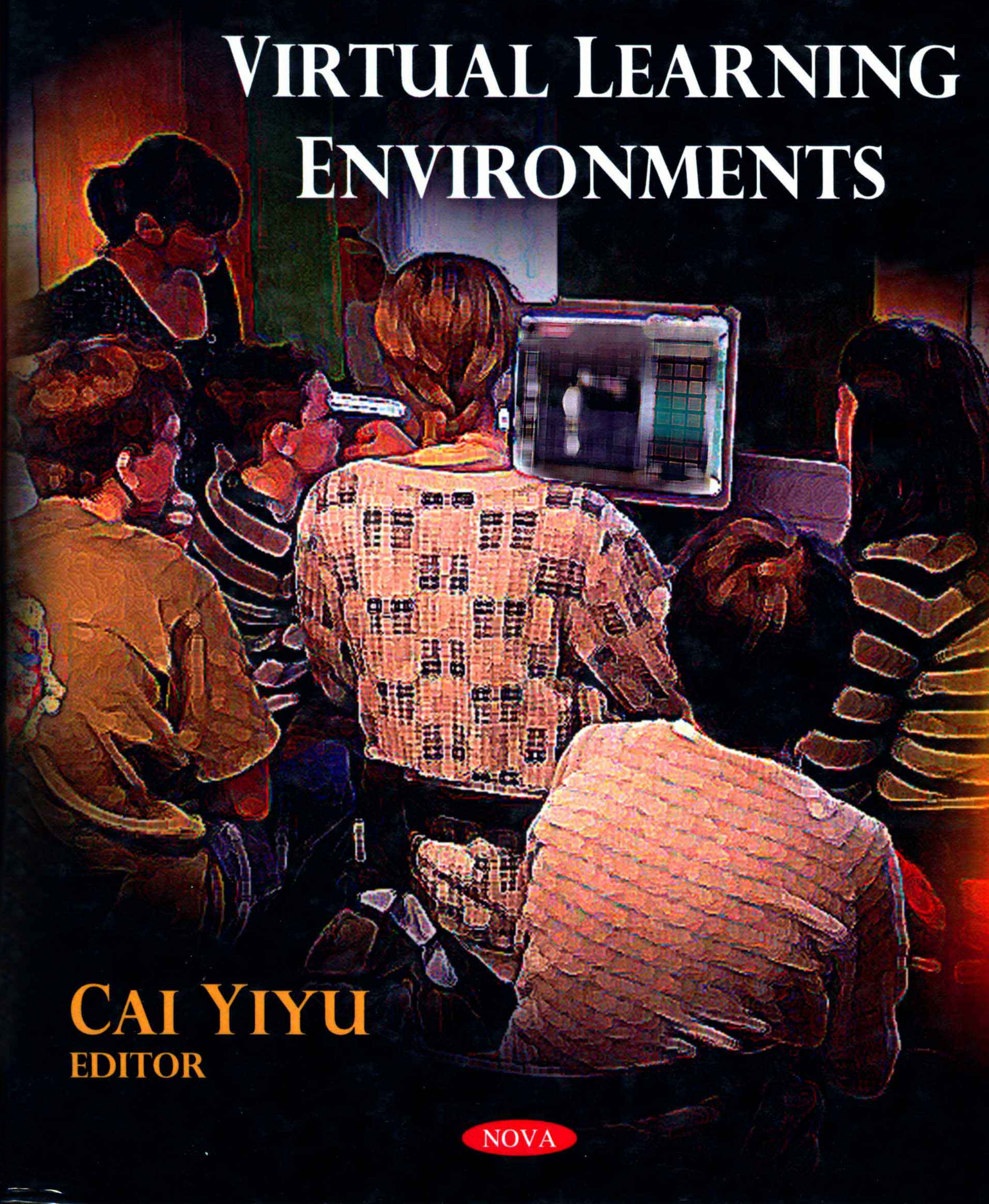
INTERACTIVE AND DIGITAL MEDIA FOR EDUCATION IN VIRTUAL LEARNING ENVIRONMENTS



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PREFACE

Education has a complex nature. The rapid globalization has called for a profound change in educational methodology, and innovative use of new educational technology. Grounded in sound pedagogy, supported by solid research methodology, and with inter-/multi-discipline background, this book provides an integrated view on this paradigm shift for education. The book presents several educational projects developed or currently under development in different countries including Denmark, The Netherlands, Sweden, UK and Singapore. The emphasis of the book is placed on the research of innovative tools and approaches, and development of new learning environments to create new knowledge that could potentially transform teaching and learning. A special interest of the book is Interactive & Digital Media (IDM) technologies that leverage interactivity and immersive visualization, foster students' critical and creative thinking, and engage students in deeper and wider learning. From a more general sense, IDM in this book refers to an interdisciplinary field covering Game, Animation, Virtual Reality, Simulation, Computer Graphics, Visualization, Human-computer Interaction, Online Virtual Community, and so on.

Educators, researchers and developers work together in this book to exchange their ideas on pedagogy, enabling technology and their learning applications. In Chapter 1, Yam San Chee from the National Institute of Education (Singapore) looks into game-based learning from the perspective of pedagogy and epistemology. In Chapter 2, Elisabet M. Nilsson and Gunilla Svingby from the School of Education with Malmö University shared their Swedish experience on Simulation and Game for Science Classrooms. In Chapter 3, Thomas Duus Henriksen from the Danish School of Education with the University of Aarhus (Denmark) investigates the issues of fun, content and realism with learning games. In Chapter 4, Karin Tweddell Levinsen from the Institute of Curriculum Studies with Danish School of Education – Aarhus University discusses the implementation of Learning Management System (LMS) in Danish educational organizations. In Chapter 5, Sara de Freitas and Ian Dunwell from the Serious Game Institute with the University of Coventry (UK) explore the implications of interactivity, immersion and fidelity on the development of serious games with Second Life as a platform. In Chapter 6, Arthur van Bilsen from Delft University of Technology (The Netherlands) describes the potential of 3D visibility analysis in Virtual Learning Environments and Interactive & Digital Media. In Chapter 7, Norman Kiak Nam Kee and Noel Kok Hwee Chia from Early Childhood and Special Needs Education with the National Institute of Education (Singapore) focuses on the discussion of mediated and engaged learning in special education for children with autism spectrum disorders using commercial-off-the-shelf video games. In Chapter 8, Ban Hoe Chow and Kah Lay So from River Valley

High School (Singapore) share their experience using Virtual Reality technology for classroom teaching and student-based project work. In Chapter 9, Gwee Hwee Ngee from Hwa Chong Institution (Singapore) presents her initial trial with her secondary school students on the novel use of Virtual Reality technology for the application in Geometry Learning.

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Chapter 1

POSSESSION, PROFESSION, AND PERFORMANCE: EPISTEMOLOGICAL CONSIDERATIONS FOR EFFECTIVE GAME-BASED LEARNING

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ABSTRACT

Educational games have been widely available since the advent of multimedia technology. Current state-of-the-art games, however, offer users 3D immersion and a depth of engagement that far exceed what was possible with multimedia. Unfortunately, the design of 3D games for education and learning has continued to lack both power and effectiveness due to a weak understanding, amongst game designers, of pedagogical and epistemological factors that are vital for designing effective game-based learning. In this chapter, I critically examine several commonly available online educational games. I argue that the weaknesses of game design stem centrally from an inadequate understanding of epistemology. I then explicate the needed epistemological understanding for effective game-based learning in terms of: (1) the fallacy of knowledge possession, (2) the inadequacy of knowledge profession, and (3) the necessity of knowing through performance. Next, I provide an example of game-based learning that illustrates how educational games can be taken to a new level of pedagogical and epistemological effectiveness. I conclude the chapter by considering some challenges to scaling up the adoption of game-based learning in schools.

KEYWORDS: game-based learning, epistemology, possession, profession, performance, *Legends of Alkhimia*, chemistry games

INTRODUCTION

Computer-based educational games have been available since the late 1980s when authoring tools such as Authorware™ and Macromedia Director™ (both now owned by Adobe Systems) became available. With the advent of Macromedia Flash™ (now also owned by Adobe Systems) in 1996, the initial trickle of educational games has grown into a sizeable flood, and computer-based games, purporting to have educational value, are now as commonplace as off-the-shelf products.

The Serious Game Initiative, launched in 2002 by the Woodrow Wilson International Center for Scholars, provided fresh impetus for the development of computer-based games that serve some kind of educational purpose rather than that of primarily entertaining the player. The term "serious game" was first coined by Abt (1970). It was used to refer to games and simulations that could be used to train decision makers in industry, government, and education, as well as in the field of personal relations. The targeted scope of application of such games is considerably wider today. The Wikipedia entry[1] for "serious game" states that the term refers to "products used by industries like defence, education, scientific exploration, health care, emergency management, city planning, engineering, religion, and politics." In a similar vein, Zyda (2005) defines a serious game as one that "uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives." From the foregoing, it should be evident that education-centric games are only a subset of the larger serious games enterprise. Furthermore, the degree to which entertainment value is regarded as essential remains moot.[2]

In this chapter, I shall focus on computer games created for game-based learning. Such games are designed to achieve explicitly targeted learning outcomes. As part of my critical considerations, I shall consider what kinds of learning processes and outcomes are meaningful and desirable from an epistemological perspective.

In the sections that follow, I shall first critique several examples of educational games that are readily available or are upheld as good exemplars by established organizations in the serious games market. Next, I shall interrogate the underlying assumptions concerning the nature of knowledge that these games implicitly adopt. As part of this interrogation, I shall argue against (1) the fallacy of knowledge possession, and (2) the inadequacy of knowledge profession; then, I shall argue in favor of (3) the necessity of knowing through performance. Drawing upon my own research, I shall describe a game that illustrates how design for game-based learning can be enhanced through a deep understanding of epistemology and pedagogy. The conclusion of the chapter will consider some challenges to advancing game-based learning in an epistemologically informed way.

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[1] http://en.wikipedia.org/wiki/Serious_games

[2] In saying this, I am not suggesting that educational games should not be fun to play. It is well known that playing computer games such as World of Warcraft involve substantial, sustained effort; hence, playing games can be "hard work." I would like to suggest instead that fun can arise from intrinsic satisfaction experienced through personally meaningful game play rather than predominantly from sensual pleasure.

Critique of Commonly Available Online Educational Games

Prensky's (2001) book on "Digital Game-based Learning" helped to popularize the use of computer games for learning. His idea of digital game-based learning is exemplified in the following quotation:

> "Most simply put, Digital Game-Based Learning is any marriage of *educational content* and computer games. The premise behind Digital Game-Based Learning is that it is possible to combine computer video games with a wide variety of *educational content*, achieving as good or better results as through traditional learning methods in the process." (pp. 145–146; italics added).

The emphasis on educational content that students are supposed to learn falls prey to Postman and Weingartner's (1969) critique of the notion that a classroom lesson is largely composed of two components, namely content and method. Content is always thought of as the "substance" of the lesson; it is something that students are supposed to "get." Such content exists independently of and prior to the student, and it is indifferent to the media by which it is "transmitted." Method constitutes the manner in which the content is presented; in this case, it is accomplished through the design embedded in the computer game. The framing implicit in this depiction of what digital game-based learning seeks to achieve is one of instructional design (Smith & Ragan, 1999) rather than learning design (Gagnon & Collay, 2006). In short, students learn the content they are taught, be it by a human teacher or by a computer game.

Let me now critically examine several examples of educational games that can be found on the Internet or for which information about these games can be readily found on the Internet. For the sake of convenience, I shall consider games in the domain of chemistry because this is one of the subject domains that I have been working in, as exemplified in the example of effective game-based learning later in this chapter.

I begin by considering an example from funbasedlearning.com. On accessing one of the links on the web page, one is presented with an instruction screen that states: "This is a fun little game that quizzes you on element names, symbols, and uses." Upon clicking the button "Start Element Quiz", one is presented with a question such as:

Hydrogen is

a. H
b. Yd
c. He
d. Hg

The onscreen hyperlink "How do I play this?" brings up the following instructions: "Click on the answer link for each question and a message will pop up letting you know if it's correct. If you miss one of the 43 questions, don't worry, it'll come up again until you get it right."

Critical readers will recognize that the questions posed on the web page are merely multiple-choice questions that form the staple diet of school assessments. It is quite remarkable that the quiz designers position this activity as a "fun little game" and even phrase the link to help information as "How do I *play* this?" (italics added). In addition, it should be evident that this model of learning with a "game" subscribes to the content and method model of teaching referred to by Postman and Weingartner. The "game designers" appear to believe that there is considerable learning value to be derived from knowing "elemental facts" such as "Hydrogen is H", "O is oxygen", etc.

Let me now consider a second example. It comes from sheppardsoftware.com. Selecting the "Chemistry Games" link, one is taken to a page with "Periodic Table Games". A typical example of such a game is one that shows the periodic table, with the following instruction: "Click on the element with the atomic mass of 58.693." If one selects the incorrect element in the periodic table, the system feedback is "Oops, that is incorrect. Please try again." A second incorrect attempt leads to the system flashing the correct element that needs to be selected. Selecting the flashing element then leads to the feedback "Correct!!!" accompanied by the presentation of extensive information about that element.

Would any student care to remember that nickel is the element that has an atomic mass of 58.693? What does the design of such a "game" suggest about the designer's conception of 'knowledge' and what is worth learning?

A White Paper on serious games that was written for Adobe Systems[3] contains many game examples that are presumably regarded as good exemplars. The section on "Games in schools" shows the following example.

What may a sponsor of the DiDA Olympics provide?

Correct!

Money would help the team with items like transport.

However: What else could they provide to support the team and perhaps promote themselves?

- Good weather
- Athletes
- Team kit
- Money

The author of the White Paper asserts: "Younger learners are also being exposed to serious games with great success. England's North West Learning Grid, for example, launched DiDA Delivered, a diploma program in IT skills for secondary students in the U.K. The curriculum includes 4,000 learning objects and 300 serious games" (p. 8).

Do serious games such as the ones illustrated above make a credible claim for educating children? Is the ability to answer content questions correctly helpful to preparing students for life in the 21st century?

Ascending the ladder of educational game sophistication, we encounter examples such as the one found at chemistryteaching.com. One particular instance focuses on atoms, symbols, and equations. Via an interface comprising both text and molecular representations, the student is tasked to "balance the equation for the combustion of methane." The left hand side of the window shows the "Reactants" methane and oxygen, while the right hand side shows the "Products" carbon dioxide and water. The student is instructed as follows: "Click on each

[3] Found at www.adobe.com/resources/elearning/pdfs/serious_games_wp.pdf

of the molecules in turn, until you have a balanced equation, then click OK." The correct answer, represented as a chemistry equation, is:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

That is, one molecule of methane and two molecules of oxygen react to form one molecule of carbon dioxide and two molecules of water. Given that the products are already stated in the body of the question, the equation balancing exercise becomes quite trivial. The student merely varies the number of each type of molecule in the chemistry equation.

Another type of chemistry "game" that can be found online is the virtual chemistry laboratory. An attractive instance of this "game" is available at virtlab.com. There is considerable sophistication in the design of the virtual laboratory and the kinds of experiments that students can perform. It appears that the designer's goal is to replace the highly constrained chemistry laboratory experiments that students typically perform in school with a digital version of the same. The instructions provided for performing the laboratory experiments are procedural. They require the student to execute a sequence of steps in strict order. However, this digital version of a chemistry laboratory is a simulation; it is not a game.

Prensky (2001, 2007) has articulated what he views as the differences between simulations and games. He states that a "pure simulation" focuses on the thing or process being simulated, while a "pure game" focuses on the user's experience. In particular, the purpose of a "pure simulation" is practice; it copies reality, is life-paced, assumes an externally defined meaning, and entails no goals, no story, and no struggle. "Pure games", by contrast, have entertainment as their purpose. They include elements of fantasy, are game-paced, require players to construct their own meaning, and involve a struggle to achieve meaningful goals within a flow of narrative. The game characteristics highlighted by Prensky are absent in VirtLab. Hence, VirtLab, while a useful learning tool, is a simulation and not a game. Its ultimate goal is to help train students' skills in typical school-based laboratory work.

Abstracting from the above examples, I draw the following inferences. First, readily available chemistry games overwhelmingly attempt to teach students chemistry content. The rationale underlying the game's design is that of "teaching content." The emphasis of such games is to drill student mastery of declarative propositions and to have students be able to state what is 'right' and what is 'wrong' (alternatively, what is 'true' and what is 'false'). Such subject content is seen as 'knowledge', an invaluable resource that teachers want students to acquire as part of the education enterprise. The second inference concerns the matter of skills. The predominant view of 'knowledge' is that it can be subdivided between declarative knowledge and procedural knowledge. Thus, apart from the knowledge-as-content focus, teachers and curriculum designers also concern themselves with the development of students' chemistry skills. To this end, the study of chemistry is accompanied by mandated laboratory sessions where students are required to execute a fixed set of sequential steps that adheres to a template of 'the right method' to perform the chemistry experiment. To perform any steps other than those included in 'the right method' would bring about penalties; there could also be dangerous outcomes. While the motivation that underlies wanting students to do the experiment 'right' is understandable, the side effect is that students never develop a deep understanding of why 'right' is (deemed to be) 'right'. In practice, 'right' can only be understood *in relation to* its opposite: namely, 'wrong'. 'Right', in isolation, can carry no meaning; 'right' can only come to mean in relation to everything else that is 'not right'. This idea is well established in the domains of semiotics (Thwaites, Davis, & Mules, 2002) and, more broadly, literary theory (Klages, 2006). While available chemistry laboratory simulation software usually permits students to commit errors, they are typically allowed to commit only inconsequential errors. Similar to intelligent tutoring systems in design, such simulations do not allow for open-ended experimentation because the developers very deliberately want students to learn only to 'do the right thing'. Taking steps that are 'not right' is viewed as not having any value for learning; it is a waste of time. Consequently, students' experience of chemistry phenomena is highly circumscribed to the subset of steps that relate to 'the right procedure' only.

To summarize, chemistry game designers, in general, make certain basic assumptions about what it means to 'learn chemistry'. First, they assume that one learns chemistry by *acquiring* 'the right answer' to factual questions. Second, they assume that chemistry laboratory sessions are intended primarily for students to experience and confirm prescribed standard experiments. Mastery of laboratory procedures is thus assessed in terms of students having *acquired* the target set of skills to execute those procedures. Are such assumptions tenable?

EPISTEMOLOGY FOR GAME-BASED LEARNING

In this section of the chapter, I wish to argue that computer games open up new pathways for learning, based on the unique aspects of learning in the first-person that the medium affords. As part of my critical interrogation of computer games as media for learning and my examination of implicit assumptions related to knowledge that are embedded in commonly available chemistry games above, I seek to make a case for a deeper understanding of epistemology in relation to game-based learning. In the section following, I then seek to illustrate the conceptual ideas with a positive example of design for game-based learning.

The Fallacy of Knowledge Possession

'Knowledge' is commonly thought of as something that a person 'has'. A recent article in the local newspaper proclaimed: "Trawling for knowledge." The article sought to highlight how easily students can 'obtain knowledge' from the Internet these days. All that students need do is 'let down their nets' on the Internet, and knowledge, like fish, will be caught. One may argue that the title merely plays on an analogy. However, analogies and metaphors powerfully reveal the underlying conceptualizations that people hold when they think and speak of various phenomena (Lakoff & Johnson, 1980).

We can trace the widespread belief that knowledge, like fish, is something that we possess to teachers who inculcate in their students, at a young age, that a dictionary contains the meanings of words. The dictionary software on my Macintosh computer, for example, provides the following definition of the word 'dog' (as a noun) among others: "a domesticated carnivorous mammal that typically has a long snout, an acute sense of smell, and a barking, howling, or whining voice. It is widely kept as a pet or for work or field sports." Students are led to believe that the meaning of the word 'dog' is *contained in* the definition and that being able to state or to recognize the definition constitutes 'having knowledge'. Thus, it is common enough to hear a classroom teacher say, "Go and find the meaning of [some word] in the dictionary." Over time, students imbibe a deep belief that memorizing propositional assertions such as the definition of the word 'dog' constitutes 'knowledge' that they 'possess'.

But what do we 'really' find in a dictionary? We find only carbon on paper, the "stuff" of which a dictionary is made (assuming that the dictionary has been produced by standard printing processes). No doubt, the carbon is laid out in very specific and stylized forms that constitute the basis of a natural language. However, it remains undeniable that, at the elemental material level, all that we have in a dictionary is carbon laid out on paper. Looking at different dictionaries will yield different definitions of the *same* word (even assuming that we choose the definition intended to convey the same *sense* of the word). This observation illustrates the claim that all we find and can ever hope to find in a dictionary is a *representation* of the dictionary author's *intended meaning*. It is not the meaning itself. Representations of meaning have no power to contain or bear meaning in and of themselves. As stated by Korzybski (1994), the map is not the territory. It is only a *representation* of the territory, and many different representations of the same territory are possible. Meaning arises instead through personal construction. It is an *interpretive* process that takes place within a social and cultural context, and it yields plausible interpretations of the author's (or the speaker's) communicative intent (Berger & Luckmann, 1966; Gergen, 1994).

The argument above is valid for *any* form of representation, including, but not limited to, images, sounds, and gestures. Hayakawa and Hayakawa (1990) explain how a symbol is not the thing symbolized. In semiotic terms, the signifier is not the thing signified. In both instances, the former term (symbol, signifier) relates to a verbal, intensional world, while the latter term (the thing symbolized, the thing signified) relates to the extensional world. The intensional and extensional are not identical. The intensional is used as a short-hand reference to denote the extensional. From an epistemological point of view, the conflation of the representation and the thing represented arises from a *dualist ontology* that assumes the existence of two distinct worlds: the 'out there' of the extensional world (we might refer to this as the 'reality' out there) and the 'in here' of the intensional world (we might refer to this as the 'reality' of our mental, in-me experience) (Gergen, 1999). This dualism is a side effect of the classical mind-body problem that assumes a *correspondence* between descriptions of the 'external' world and descriptions of the 'internal' mental world. However, as Gergen makes clear, no one-to-one correspondence is possible between what happens 'out there' and our descriptions of it 'in here'. To reinforce the point, try the following thought experiment. Take any five people who have just shared a common experience, and ask them to describe that experience individually. What will you get? You will obtain five different accounts, often very different from one another.

What then of the common view that human memory is the place where we 'store' our knowledge? If knowledge, unlike fish, is not a thing as I have argued, clearly it cannot be stored, whether in a memory data store or some other form of storage. The view of memory as a data store of some kind arises directly from the computer metaphor adopted by the psychology of human information processing. It is indeed noteworthy that early experimental work by Bartlett (1932) on what we would commonly call memory experiments today was framed in terms of the cognitive process of *remembering*. The idea associated with the term "memory" was not that memory is a store for mental objects but, rather, of memory as a *process*. Likewise, Rosenberg (1988) argues that memory, as it is widely conceived, is an invention: a piece of make-believe that has no credible basis in light of what is known from neuroanatomy and neurophysiology today. It is simply not credible to assert that brains have the ability to store symbolic and image representations qua symbolic and image representations (Damasio, 1994). Such an assertion gives rise to a fundamental type mismatch error. If one then accepts the argument that (1) knowledge is not a 'thing' and, furthermore, that (2) knowledge is not stored in memory because memory is a process of remembering rather than a knowledge store, it follows that humans cannot and do not possess knowledge *as commonly conceived*. To believe otherwise is to accept the fallacy of knowledge possession. Denying the fallacy of knowledge possession also implies that knowledge *cannot* be transmitted from one person to another. This understanding raises deep issues for the practice of teaching and learning in schools.

The Inadequacy of Knowledge Profession

The argument that knowledge is not a thing naturally begs the question, "What then is knowledge?" Allen Newell, in delivering his presidential address to the American Association for Artificial Intelligence in 1980, already echoed his own misgivings about the widespread conception of knowledge as a thing. He suggested instead that "knowledge is a competence-like notion, being a *potential* for generating action" (Newell, 1982, p.100, italics added). Recognizing that encoded knowledge representations of programmed behaviors (in the context of artificial intelligence) only create a potential to act intelligently, we might say that Newell conceived of knowledge as 'actionable knowledge'; that is, knowledge must be manifestable through *action*. We propose that a better term for 'actionable knowledge' is 'knowing' as this latter term more strongly connotes knowledge-in-action. When people act in a knowing way, they provide us with a basis to *impute* having knowledge. But to do so would entail accepting the fallacy of knowledge possession discussed above, something that I do not wish to do.

Based on the discussion above, it becomes important to distinguish between a person's ability to merely state or articulate ideas, that is, to profess 'knowledge', and that person's ability to act in ways that actualize the ideas in ways that are productive and useful both to him or herself as well as to others. In this sense, then, to profess knowledge is merely to articulate representations of knowledge. It is distinct from being able to *enact* what that 'knowledge' may entail in everyday life. An example that illustrates this point clearly is the case of swimming. The value of learning to swim lies in the act: the ability to swim so that one does not have to drown in water, etc. But the ability to swim is vastly different from the ability to deliver a lecture *about* swimming. The word 'about' signifies that one is operating in the realm of knowledge representation, not the realm of knowing as a capacity to act in the world. The difference in outcomes between swimming and lecturing about swimming and the relative value associated with each of those outcomes should be self-evident. On their own, verbal professions are cheap and plentiful. The uncomplimentary saying that "those who can, do; while those who can't, teach" illustrates the argument. However, making this assertion would only reflect on the speaker's own limited understanding of the challenges that educators face in facilitating student learning. They do not "merely teach". The mere (verbal and expository) profession of 'knowledge' is of very limited efficacy for genuine learning, as any student who has been on the receiving end of 'lectures' will attest to. In a similar vein, Minick (1987) has distinguished between communication *about* words and communication *with* words. The former is typical of communication within schooling while the latter marks a capacity to use words instrumentally in everyday actions. Thus, knowledge profession falls short of the enterprise of educating students. Being told does not automatically translate into the ability to enact or perform what one is told (Chee, 2002). Knowledge profession is thus inadequate.

The Necessity of Knowing Through Performance

The notion of performance derives from theatre studies (Schechner, 2003, 2006). In this domain, performance is always a form of enaction (Masciotra, Roth, & Morel, 2007). It involves a form of patterned behavior that entails repeated doing and re-doing. Consider a concert pianist who practises extensively for a recital. Practice on the piano clearly requires repeated playing and re-playing of the concert pieces. More important is the pianist's self-consciousness of the doing and re-doing. Such activity is both reflexive as well as reflective. The pianist is able to make himself the subject or focus of critical attention. With this reflexive perspective, the pianist experiences a "double consciousness": that is, there is a distinct awareness of that which is *actual* (how she actually played) and that which is *ideal* (how she actually wished to play). It is this tension between consciousness of an actual performance contrasted with that of an ideal performance that makes players aware of discrepancies between actual and ideal. The learning of the individual is propelled by awareness of the discrepancies between the actual performance and the ideal performance.

Enactive knowing, via performance, is inherently embodied in nature. A person engages in performance with his entire bodily being, or self. Learning, from this point of view, therefore entails transformations that relate to the entire self, not just the person's 'mind'. In this conception, it is the *person* that learns, not the 'mind' of the person. What, after all, is a mind? It is surely not an object that we possess. (Should the reader think otherwise, he is invited to locate where his mind resides.) Like 'knowledge', 'mind' is not an object that a person might have one (Chee, Tan, & Lee, 2010). An alternative framing is to understand a 'mind' as being imputed to persons who demonstrate the capacity of minding, as explained by Geertz (1973).

Following from the above, the site at which there is a tension between an actual performance and the ideal performance is a site for learning to take place. Indeed, it is this very tension between the actual and the ideal that drives learning forward. This site constitutes a border area where new negotiations of meaning and inventions of new practices can take place. Such border areas are the source of new ideas and new cultural practices.

Coming to know is therefore not a matter of mastering 'content' at all. Rather, it requires that learning take place in the context of inquiry into (some aspect of) life itself. This form of learning was clearly espoused by Dewey (Dewey, 1938/1991; Hickman, 1998). It is based on a conception of education as "the process of forming fundamental dispositions, intellectual and emotional, toward nature and fellow-man" (Garrison, 1998, p. 63). Fundamental to this conception is the paramount importance of the unity of "trans-action" between the learner, always a part of nature, and the rest of nature. In this mode of behavior, activity is the primary mode of learning. As explained by Garrison (1998, citing Dewey), the idea and the emotional excitation are constituted at one and the same time, and they represent the tension of stimulus and response within the coordination that makes up the mode of behavior. Explicit thinking arises a moment later, upon analysis and abstraction, as part of a process that discriminates between the organism (or learner) and the environment. Thus, coming to know does not arise from 'justified true belief', an assertion of classical epistemology, where logical forms are *imposed* on the subject matter of inquiry. Instead, the epistemology advocated here is a *performance epistemology*, one that views and values knowing as an ability to perform in ways that create personal, social, economic, and creative value. In this sense, therefore, we argue in favor of the necessity of knowing through performance, a pragmatic stance that is consonant with Dewey's philosophy.

GAME-BASED LEARNING GROUNDED ON PERFORMANCE EPISTEMOLOGY

We have been developing a game for chemistry education at the lower secondary school level in Singapore. The game, *Legends of Alkhimia*, instantiates a learning environment for students to learn chemistry by *doing* chemistry as part of a process of learning by inquiry (Dewey, 1938/1991; Postman & Weingartner, 1969), rather than learning *about* chemistry in order to "acquire chemistry knowledge." The game comprises eight levels of game play. It is a multi-player game that supports up to four students in each game session. Students learn chemistry within a framework of game-based learning called the Play–Dialog–Performance (PDP) Model (Chee, in preparation). This model of learning is technology mediated, through the artifact of the computer game, as well as socially mediated, through a dialogic mode of learning (Bakhtin, 1981; Wells, 1999) that takes place in a teacher-facilitated classroom context.

The game begins in Level 1 with a scenario where the four players crash-land in the environs of the ancient town of Alkhimia. They have with them certain weapons, a form of gun, that shoot ammunition drawn from cartridges attached to the weapons. On exiting their aircraft and surveying the surroundings, several monsters, emerging from a narrow mountain passageway, suddenly attack them. The players use their weapons against the monsters. (See Figure 1.[4]) However, they find that their weapons often jam, and their ammunition is of limited effectiveness against the monsters. After a short and furious battle, the monsters retreat back into the mountains. The players wonder why their weapons were prone to jamming. They also wonder about the composition of their ammunition and why it failed to kill the monsters.

The game narrative above sets the context for student engagement in a process of inquiry. Prior to entering into the game world, the players are positioned by the game as aspiring scientists (chemists) who learn their craft under the tutelage of their boss, Master Aurus. In the game lobby, they choose their in-game name. They also select their personal look in the player customization screen in a manner that reflects their sense of personal identity at the commencement of the game. Figure 2 illustrates the different attributes that a player can

[4] Note that the user interface elements are incomplete at this time because the game is still in development at the time of writing.