Fostering Scientific Habits of Mind in the Context of Online Play

Abstract: In today's increasingly "flat" world of globalization, the need for a scientifically literate citizenry has only grown more urgent; yet, by some measures, we have done a poor job at fostering the right *scientific habits of mind* in schools. Recent research on informal games-based learning indicates that such technologies/communities may be one viable alternative – not to teachers and classrooms but to textbooks and science labs. In this paper, we provide empirical evidence substantiating previous claims about the potential of games for learning and offer specific *design heuristics* that might inform their future production and use. Using codes based on AAAS benchmarks and Chinn and Malhotra's (2002) framework for evaluating inquiry tasks, we examine the scientific habits of mind that characterize online discussion forums of the MMOG *World of Warcraft* and the features of the game – both as designed object and emergent culture – that appear to foster them.

Scientific Literacy: More than Stones

In 1905, at a gathering of the world's greatest minds in the physical sciences, Henri Poincare reflected on the rapid progress of scientific inquiry and the means through which the scientific community at the turn of the 20th century and beyond would refine our understanding of the world. In his historical address, Poincare warned against the seduction of reducing science to a domain of seeming facts, stating, "Science is built up of facts, as a house is built of stones; but an accumulation of facts is no more science than a heap of stones is a house" (1905/2001, p.141). One hundred years later, his admonition against the framing of science as a "rhetoric of conclusion" (Schwab, 1962, p.24) still holds, with science scholars and educators from Dewey on repeatedly warning us against the teaching of science as only content rather than process. In Dewey's own words, "the future of our civilization depends upon the widening spread and deepening hold of the *scientific habit of mind* [italics added]… the problem of problems in our education is therefore to discover how to mature and make effective this scientific habit" (1910, p.127).

In today's increasingly "flat" world (Friedman, 2005) of massive globalization and technological interconnectivity, the need for a scientifically literate citizenry in the United States has only grown more urgent; yet, by some measures, it seems we have done a poor job at fostering the right habits of mind in our schools. Currently only one in five Americans are scientifically literate (Miller, 2004) despite mandatory instruction. In a recent study of contemporary classroom practice, Chinn and Malhotra (2002) found that standard "inquiry" activities not only failed to engender scientific habits of mind but in fact actually fostered epistemological beliefs directly *antithetical* to them. Recent assessment of high school laboratory activities by the National Research Council (Singer, Hilton, & Schweingruber, 2005) reach similar conclusions: science labs, long heralded as *the* site for engaging students in science practice, fail. Meanwhile, as our national quandary over how to teach scientific theory of human origins demonstrates (Chmiel & Owens, 2005), the misconception of science as "built up of facts" rather than intellectual practices only compounds, leaving the public increasingly hostile to the scientific enterprise itself (Elsner, 2005). Perhaps as Gates (2005) argued in his National Education Summit address, American schools have become obsolete: "Training the workforce of tomorrow with the high schools of today is like trying to teach kids about today's computers on a 50-year-old mainframe. It's the wrong tool for the times" (¶12).

Leveraging Online Play

But, if our educational system is not the right "tool for the times," what is? Despite dismissals as "torpid" and inviting "inert reception" (Solomon, 2004) in some mainstream press, videogame technologies may be one viable alternative – not to teachers and classrooms but rather to textbooks and science labs. Recent studies indicate that the intellectual activities that constitute successful gameplay are nontrivial, including the construction of identities (Gee, 2003; Steinkuehler, in press), collaborative problem-solving (Squire, 2005; Steinkuehler, 2006; cf. Nasir, 2005), literacy practices that exceed our national standards (Steinkuehler, 2005b), systemic thinking (Squire, 2003), and, as one might expect, computer literacy (AAUW, 2000; Squire & Steinkuehler, 2005). Games, however, are more than just the sum of their intellectual practices (as important as those may be); they are, in fact, *simulated worlds*:

> The first step towards understanding how video games can (and we argue, will) transform education is changing the widely shared perspective that games are "mere entertainment." More than a multi-billion dollar industry, more than a compelling toy for both children and adults, more than a route to computer literacy, video games are important because they let people participate in new worlds. (Shaffer, Squire, Halverson, & Gee, 2005)

As simulations, games allow "just plain folk" (Lave, 1988) to build situated understandings of important phenomena (physical laws, for example) that are instantiated in those worlds amid a culture of intellectual practice that render those phenomena culturally meaningful (Steinkuehler, 2006). Their potentials for learning have not gone unnoticed, and the last two years have witnessed a marked rise in interest across various academies in leveraging game technologies toward educational ends: the Woodrow

Wilson Foundation's Serious Games Initiative, the Games, Learning and Society program at the University of Wisconsin-Madison, the Education Arcade project at MIT, the Games for Social Change Movement, and Stanford University's Media X "Gaming To Learn" Workshop, to name a few.

One genre of videogame in particular offers distinctive promise in terms of fostering scientific habits of mind: *massively multiplayer online games*. Massively multiplayer online games (MMOGs) are 2- or 3-D graphical, simulated worlds played online that allow individuals to interact, through their digital characters or "avatars" not only with the designed environment in which activities take place but also with other individuals' avatars as well. Previous ethnography of such online worlds demonstrates their function as naturally occurring learning environments (Steinkuehler, 2004, 2005a), yet the forms of scientific argumentation, model-based reasoning, and theory-evidence coordination that arise in the context of MMOG play warrant further investigation. In MMOGs, individuals collaborate to solve complex problems within the virtual world, such as figuring out what combination of skills, proficiencies, and equipment are necessary to conquer an in-game boss monster. As part of developing efficient and effective solutions, players are customarily expected to research various game strategies and tactics by consulting on- and offline manuals, databases, and discussions and by using such knowledge as the basis for in-game action. Thus, as part of standard gameplay (particularly beyond the beginning levels), individuals share their own hypotheses about what strategies work by proposing models for solutions, justifying their "theories" with evidence (such as tabulated mathematical results aggregated across multiple trials), and debating the merits of conflicting hypotheses – not as aimless contentious discussion (although there is a bit of that as well) but rather as part and parcel of the collective intelligence (Levy, 1999) amassed through patterned participatory consumption (Jenkins, 1992) the hallmark of interactive "entertainment" media such as games.

Innovative NSF projects such as Harvard University's *River City* (e.g., Dede, Ketelhut, & Ruess, 2003) and Indiana University-Bloomington's *Quest Atlantis* (e.g., Barab, Arcici, & Jackson, 2005) have begun to tackle the complexities of designing MMOGs for science learning, offering projects of concept of the argument presented above. Yet, as Lave and Wenger (1991) note, understanding informal contexts for learning is crucial if we are to forward educational theory and practice beyond the contexts we ourselves contrive. Therefore, in order to forward our understanding of the forms of scientific reasoning that emerge as a natural part of gameplay in informal MMOGs and the design features that appear to foster them, this paper presents an examination of an online forum discussion of the "off the shelf" MMOG *World of Warcraft*. In this investigation, we analyze a threaded discussion in which participants attempt to work out a best-fit solution to one of the MMOG's in-game mechanics: the "druid talent build." Using codes based on the AAAS benchmarks for scientific literacy (AAAS, 1993) and Chinn and Malhotra's (2002) theoretical framework for evaluating inquiry tasks, we highlight the scientific habits of mind displayed within the discussion and the features of the game – both as designed object and emergent culture – that appear to foster them. Our goal here is to move beyond arguments about the *potentials* of MMOGs for learning by ferreting out which *specific* scientific literacy practices emerge within such game-related online communities (and which do not) and then, based on those findings, take a first step toward developing *MMOG design heuristics* that might inform and enable future instructional design.

Data Collection & Research Methods

Context of the Research & Data Corpus

The context for this investigation is *World of Warcraft*, a successful MMOG released in November 2004 and currently boasting the single largest share of the market in North America and well over four million subscribers globally. The game is set in a fantasy world in which players of various classes (eight total) wander the environment hunting, gathering, questing, battling, and crafting in order to strengthen or "level" their character in various ways. The data analyzed for this particular study consist of a threaded discussion that took place mid-October of 2005 on the "druid forum" of the official *World of Warcraft* website. Although there are a number of relevant online forums to be found, the official website alone features 24 separate forums totaling well over 40,000 separate, active threads; therefore, we chose to limit our data corpus by selecting a discussion thread that (a) was contained within one of the character class-related forums (rather than, say, the general discussion forum which includes off-topic socializing), (b) related to specific in-game problem-solving (here, druid talent builds, discussed below), (c) began with a question (given the forms of reasoning under investigation), and (d) had a high number of "unique account views" (i.e., was read by a large number of players). The discussion thread selected for analysis, comprised of 75 individual posts by 31 individuals, was entitled "Imp Mark of the Wild" and the content of the first post consists of a single, simple question: "Why is it nearly every template I see skips this ability?" A bit of context is necessary, however, in order to make sense of this initial query.

In *World of Warcraft*, players individualize their avatar by allocating talent points, earned through time spent hunting in game, across the various tiers within their class-specific "talent tree" (see Figure 1). "Imp Mark of the Wild" refers to one talent that one class of players, *druids*, can choose to invest in. These refinements, represented as selections within the talent trees, are commonly manifested statistical improvements of some form or another to one's current abilities. For example, by investing five talent in the "Improved Mark of the Wild" branch on the skill tree rather than another, a druid can get a 35% increase in the effect of their armor-enhancing buff spell named "Mark of the Wild," thereby improving her function in some collaborative problem-solving situations and decreasing her capability in others. Such choices impact one's contributions in in-game collaborative problem-solving functions; therefore, a great deal of communal value placed on making wise choices when developing one's particular "talent build." Players convene in online discussion forums to discuss and debate the merits of different builds, at times even refusing to play with others who have made choices that go against the communal wisdom developed therein. Thus, *World of Warcraft* participants have good reason to pay close attention to forum discussions as they represent the collective work of many toward developing best-fit solutions for specific groups, and it is not unusual to have discussion threads that receive 300,000+ unique account views. In the forum thread analyzed herein, a non-druid player asks why a skill improvement called "Improved Mark of the Wild," is left out of many recently fan-posted druid talent templates or "builds." In response, community members offer various competing theories, arguments, and evidence for what constitutes the most efficacious use of the limited resource of talent points.

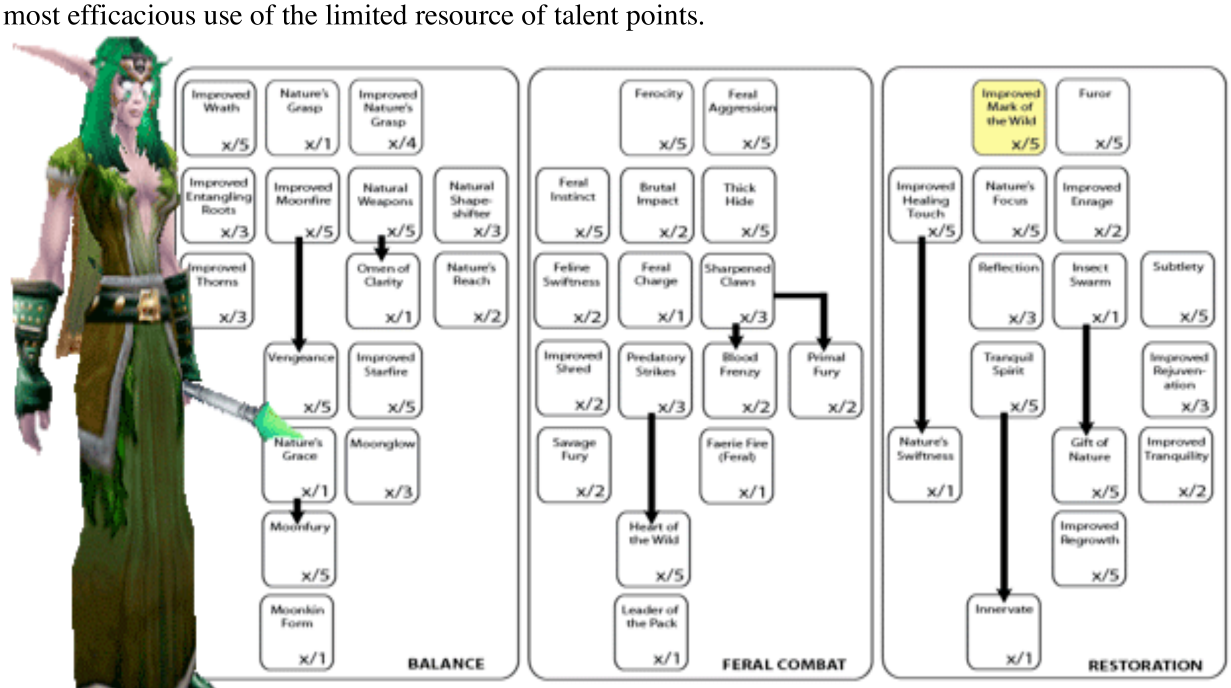

Figure 1. The *World of Warcraft* (night elf) druid and corresponding talent tree.

Method of Analysis

In order to assess the *scientific habits of mind* that characterize (or fail to characterize) the data corpus examined here, we developed a set of codes based in combination on a subset of the AAAS benchmarks for scientific literacy (AAAS, 1993) and Chinn and Malhotra's (2002) theoretical framework for evaluating inquiry tasks. The codes were selected from these sources based on a combination of a priori assumptions about the forms of scientific reasoning such spaces ought to generate (e.g. understanding systems and feedback among components of a system) and previous games related literature (Gee, 2003; Squire, 2003, 2005; Steinkuehler, 2004, 2005a, 2005b). Figure 2 (below includes the full list of 21 codes; Table 1 presents a subset (given space constraints) of their definitions.

Table 1. A subset of the analytic codes used to assess scientific habits of mind.

Scientific Discursive Practices
• **Build on Others' Ideas.** Restate or summarize others accurately what others have said, ask for clarification or elaboration, and express alternative positions (AAAS, 1993)
• **Multiple Forms of Argument.** Employ multiple forms of argument, not only simple deductive reasoning (Chinn & Malhotra, 2002)
Model-Based Reasoning
• **Systems Analysis.** Understanding systems analysis, specifying its boundaries and subsystems, indicating its relation to other systems, and identifying its inputs and outputs (AAAS, 1993)
• **Mathematical Models as Insight.** Understanding mathematical modeling as finding a mathematical relationship that behaves in the same ways as the objects/processes under investigation and that such models may or may not give insight into how those objects/processes work (AAAS, 1993)
Understanding Theory & Evidence
• **Pragmatic Understanding of Theory.** Understanding that, no matter how well a theory fits observations, a new theory might fit them as well or better and that the ongoing process of testing, revising, and occasionally discarding theories leads to better but not to absolute truth (AAAS, 1993)
• **Theory-Data Coordination.** Coordinating one's theoretical model with multiple sets of complex, sometimes partially conflicting data (Chinn & Malhotra, 2002)

Findings

The results from this analysis are presented in Figure 2, which shows the percentage of posts that exhibit each scientific habits of mind for which we coded. Here, we see the saturation of key characteristics of scientific reasoning skills across the set of 75 posts that comprise the selected threaded discussion. Several interesting patterns emerge from this analysis.

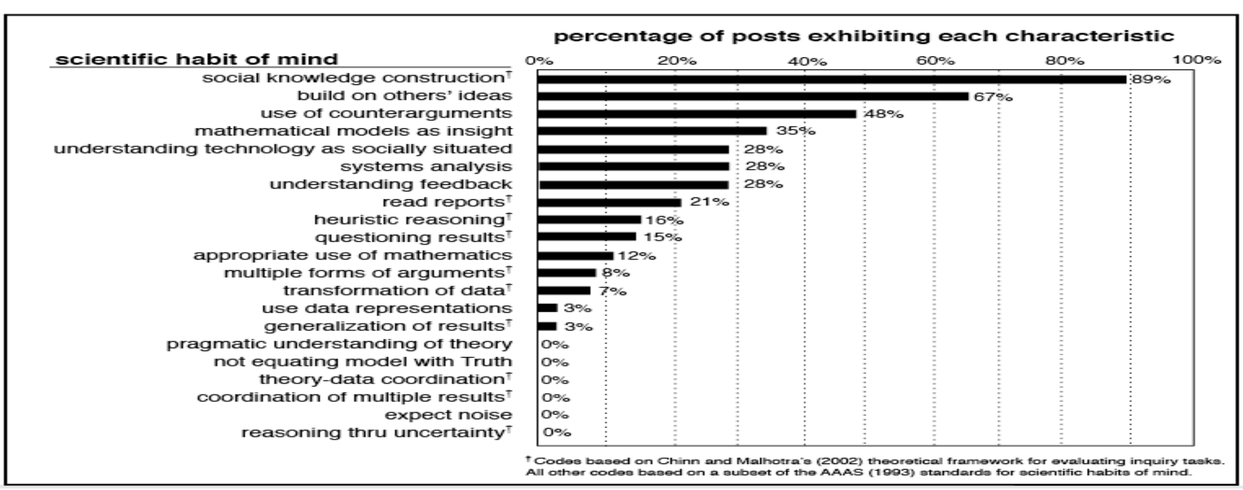

Figure 2. Proportion of posts within the data corpus that exhibit each scientific habit of mind.

Scientific Discursive Practices

First, *scientific discursive practices* such as collaborative knowledge construction, building on the ideas of others, and the use of counterarguments are the most prevalent scientific habit of mind exhibited by posts within the discussion. That *World of Warcraft* players engage in mindful discussion and debate should come as no surprise given the "collectively intelligent" (Levy, 1999) nature of such communities; however, it is interesting that forms of *scientific* argumentation are prevalent within this informal context findings that indicate that such practices do not come naturally and are difficult to foster (Kuhn, 1991; Osborne, Erduren, & Simon, 2004). In these data, is not unusual for participants to explicitly reference the reports of others, question one another's results, and leverage mathematical data as evidence for one's thesis. The following post illustrates:

> I see this over and over again in threads and I think it is myopic. Playing the percentages alone is narrow and limited thinking… Repeat after me, an increase is an increase… would you rather have 285 or 385, 12 or 16, 20 or 27? …like everything else in this amazingly complex game, there are trade-offs and often times things are situational. Furor [alternative to Improved Mark of the Wild], as a couple of the other posters point out, is solo-buffing whereas MoTW [Mark of the Wild] is group-buffing. [post #59]

Model-Based Reasoning

Second, forms of *model-based reasoning* such as understanding systems, feedback mechanisms among their components, and the usefulness of describing them as mathematically are also regularly displayed by discussion participants (close to one third of all posts), although to a lesser extent than the scientific discursive processes discussed above. Given the design of character improvements within the game (i.e. the druid talent tree), participants are faced with the challenge of finding the best-fit solution to a problem of limited resources (talent points) for distribution across multiple variables, each with their own mathematical relationship to underlying avatar characteristics (e.g., hit points, mana points, regeneration speed). Thus, within the fantasy context of orcs and druids, heals and buffs, participants sometimes find themselves engaged in explicit analyses of complex systems. Consider, for example, the following post in which a participant compares various potential states of the druid talent tree in order to claim the superiority of one final template or build over another:

> …To get what I want to get in Balance [first subsystem of the druid talent tree] while still majoring in Feral [second subsystem] (31/32pts), I can only afford 5 points for Restoration [third subsystem]. Considering the rest of my build (Feral), I'm far better off getting instant rage/ energy on shift [benefits of "Furor, an alternative to "Mark of the Wild"] than I am blowing those points on IMoTW [Improved Mark of the Wild]. Keep in mind, IMoTW [Improved Mark of the Wild] only increases MoTW's [Mark of the Wild's] effect by 35%, it is not an overall 35% buff. At L60 [level 60] that translates to +100 armor, +4 attributes and +7 to resists over the unimproved L60 [level 60] MoTW [Mark of the Wild]. While every little bit helps, for those precious 5 points, Furor [alternative to Improved Mark of the Wild] helps a lot more… [post #3]

Notice, however, that two key scientific habits of mind related to model-based reasoning are entirely absent: (1) awareness that, even in simple systems, it may not always be possible to accurately predict the result of changing some part or connection ("expect noise"), and (2) realizing that even a close match between a model's predictions and observations does not necessarily mean that the model is the only "true" model or one that would work ("not equating model with 'Truth'"). Both habits of mind are crucial to understanding the appropriate function and use of models in science, yet neither emerges throughout the discussion. One explanation may be that model-based reasoning in the context of synthetic worlds takes on the characteristics of *reverse engineering*, operating under the assumption that there *is* a single correct algorithm underlying phenomena and it is only a matter of finding it (discussed below).

Understanding Theory & Evidence

Finally, scientific habits of mind related to understanding the function and relationship of *theory and evidence* are noticeably rare among posts within the discussion. Although participants do, on occasion (roughly one tenth of all posts), engage in heuristic rather than simple algorithmic reasoning and transform their observations into alternative data formats, other related scientific habits of mind are nearly or completely absent. In only three percent of the posts do individuals tackle the potential generalizability of their solutions and we find no evidence of individuals coordinating their theories with multiple sets of data, reason through uncertainty in their arguments, or displaying a pragmatic understanding of theory (defined above). If we treat the entire *discussion group* as our unit of analysis (aggregating across all 31 individuals), these features actually emerge; however, it remains an open question as to whether *individual participants* might be ascribed them rather than the group. If so, it may be that the disputative nature of online forum discussions (a product of the fact that agreements are rarely posted, Hine, 2000) simply discourages expressions of uncertainty, noise or doubt.

Design Implications

Again, our goal has been not only to provide empirical evidence to substantiate claims of the potential of MMOGs as sites for studying science learning but also to offer a beginning set of heuristics that might inform the future design of intentional learning environments. Analysis of the scientific habits of mind that characterize the data corpus examined here reveal patterns in the forms of scientific argumentation, model-based reasoning, and theory-evidence coordination that arise in the context of online discussion of MMOG play. These patterns point to specific characteristics of MMOGs, both as designed objects and emergent cultures that *afford* the emergence of some scientific habits of mind and *constrain* others, patterns that could be of use to designers of online mediated environments for learning science. Of particular interest to designers of learning environments may be the way that model-based reasoning in the context of synthetic worlds takes on the characteristics of *reverse engineering*, operating under the assumption that there *is* a single correct algorithm underlying phenomena and it is only a matter of finding it, a condition that is bound to be true of any game-based learning environment.

MMOGs contain *designed experiences* analogous to any well-crafted piece of instruction, yet they are also fully realized simulated *worlds* exhibiting emergent, unpredictable properties that set an impressive standard of scientific thinking to which our designed learning environments (e.g. *River City*, *Quest Atlantis*) can aspire. Unlike the simple one or two variable experiments characteristic of science classrooms, MMOGs offer multivariate problems of real complexity and of genuine social import to those solving them. Model-based reasoning can be fostered by giving groups complex systems to work with whose outputs are consequential (in this case, they change the very nature of one's virtual body or avatar). Problem-solvers are therefore *stakeholders* in that efficient and effective solutions become the basis for future action, both their own and that of their peers. In these ways, the forms of inquiry such virtual worlds afford are *authentic even though synthetic*: While science classrooms often focus on questions that can be answered with Google, MMOGs capture a more authentic sense of inquiry, oftentimes requiring enormous teams of people doing simultaneous, partially overlapping, partly conflicting lines of research – much like science out "in the wild." Scientific discursive practices emerge when participants are given the chance to solve such problems and the opportunity to make a genuine contribution to the collective intelligence (Levy, 1999) of their community in which solutions developed by one person are referenced and built upon by others.

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