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Scientific Habits of Mind in Virtual Worlds

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Abstract In today's increasingly "flat" world of globalization (Friedman 2005), the need for a scientifically literate citizenry has grown more urgent. Yet, by some measures, we have done a poor job at fostering *scientific habits of mind* in schools. Recent research on informal games-based learning indicates that such technologies and the communities they evoke may be one viable alternative—not as a substitute for teachers and classrooms, but as an alternative to textbooks and science labs. This paper presents empirical evidence about the potential of games for fostering scientific habits of mind. In particular, we examine the scientific habits of mind and dispositions that characterize online discussion forums of the massively multiplayer online game *World of Warcraft*. Eighty-six percent of the forum discussions were posts engaged in "social knowledge construction" rather than social banter. Over half of the posts evidenced systems based reasoning, one in ten evidenced model-based reasoning, and 65% displayed an evaluative epistemology in which knowledge is treated as an open-ended process of evaluation and argument.

Keywords Informal science reasoning · Virtual worlds · Social knowledge construction · Game-based learning · Informal learning

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In 1905, at a gathering of the world's greatest minds in the physical sciences, Henri Poincaré reflected on the rapid progress of scientific inquiry and the means through which the scientific community at the turn of the twentieth century and beyond would refine our understanding of the world. In his historical address, Poincaré 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). A century 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 world 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 science. 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 et al. 2005) reaches similar conclusions: science labs, long heralded as *the* site for engaging students in science practice, fail. Meanwhile, the public seems to grow increasingly hostile to the scientific enterprise (Elsner 2005).

Leveraging Online Play

But, if the inquiry activities used currently in education are unable to foster the right attitudes toward science, what can? Games, potentially. Despite dismissals as "torpid" and inviting "inert reception" (Solomon 2004) in some mainstream press, videogame technologies may be one viable alternative—not to the role of teachers and classrooms in learning science, but rather to textbooks and science labs as educational experiences about the inquiry process. Recent studies indicate that the intellectual activities that constitute successful gameplay are nontrivial, including the construction of new identities (Gee 2003; Steinkuehler 2006b), collaborative problem solving (Squire 2005; Steinkuehler 2006a; cf. Nasir 2005), literacy practices that exceed our national standards (Steinkuehler 2007, 2008a), systemic thinking (Squire 2003), and, as one might expect, computer literacy (Hayes and Games in press; Steinkuehler and Johnson, 2007, unpublished manuscript).

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, and Gee 2005, p. 106)

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 2006c). Their affordances 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 (MMOs) 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. For example, five friends or strangers could create an impromptu group and go hunting "boss" dragons in one of the virtual world's more difficult dungeons. Previous ethnography of such online worlds demonstrates their function as naturally occurring learning environments (Steinkuehler 2004, 2005), yet the forms of scientific argumentation, model-based reasoning, and theory-evidence coordination that arise in the context of MMO play warrant further investigation.

In MMOs, individuals collaborate to solve complex problems within the virtual world, such as figuring out what combination of individual skills, proficiencies, and equipment are necessary to conquer an in-game boss dragon in the example above. 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, as well as by using such knowledge as the basis for in-game action. Such research might include, to continue our example, consulting collective online databases about where the boss dragon lives, what its special skills are, and what previous strategies have been successful.

Members of the group then come to the activity well-versed in known research on the problem and enter into collaborative work under the mutual expectation that each will apply known information to the solving the problem. Should the solution not prove to be straightforward, the group learns from what fails, discounting some solution paths while raising others. In prior ethnographic work (2005), Steinkuehler found that it was not unusual for players to gather data about a specific monster or challenge in the virtual world in Excel spreadsheets, create models of the data in the form of simple mathematical equations, and then argue about whose model was "better" in terms of prediction and explanatory scope.

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 debate the merits of conflicting hypotheses. This collaborative construction of knowledge, parallel to what takes place in the scientific community, is not aimless contentious discussion (although there is a bit of that as well), but rather part and parcel of the *collective intelligence* (Levy 1999) amassed through patterned participatory consumption (Jenkins 1992), which is a hallmark of interactive "entertainment" media such as games.

Innovative projects such as Harvard University's *River City* (e.g., Ketelhut 2007; Ketelhut et al. 2007; Nelson et al. 2007) and Indiana University-Bloomington's *Quest Atlantis* (e.g., Barab et al. 2005; Barab et al. 2007) have begun to tackle the complexities of designing MMOs for science learning, offering proof 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 advance educational theory and practice beyond the contexts we ourselves contrive. Therefore, in order to extend our understanding of the forms of scientific reasoning that emerge as a natural part of gameplay in informal MMOs and the design features that appear to foster them, this paper presents an examination of discussions on the official online forum for the commercial MMO *World of Warcraft*.

In this investigation, we analyzed a random sample of nearly two thousand discussion posts in which participants discuss various game-related topics. Using codes based on national benchmarks for scientific literacy (American Association for the Advancement of Science 1993), Chinn and Malhotra's (2002) theoretical framework for evaluating inquiry tasks, and Kuhn's (1992) epistemological framework, we highlight the scientific habits of mind displayed within the forum discussions and the features of the game—both as designed object and emergent culture—that appear to foster them. This study moves beyond arguments about the *potential* of MMOs for learning by documenting and assessing which *specific* literacy practices emerge within such game-related online communities (and which do not). Based on those findings, we then take a first step toward identifying the characteristics of MMOs that may be enabling such practices to emerge.

Data Collection and Research Methods

Context of the Research and Data Corpus

The context for this investigation is *World of Warcraft* (*WoW*), a successful MMO released in November 2004 and currently boasting the single largest share of the global MMO market with well over ten million subscribers globally (Woodcock 2008). The game is set in a fantasy world in which players of various classes (nine total, at the time of this article's writing) 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 threaded discussions that took place early November of 2006 (before the release of the expansion, *World of Warcraft: The Burning Crusade*) on the "priest forum" of the official *World of Warcraft* website (http://forums.worldofwarcraft.com). Although there are a number of relevant online forums to be found, the official website alone featured 31 separate forums totaling well over 270,000 separate, active threads. Therefore, we chose to limit our data corpus by selecting a single character class-related forum (shown in Fig. 1) rather than, say, the guild recruitment or bug report forum. Class-related forums are just like any other discussion forum, except the content is ostensibly focused on class-related topics for discussion. Content is not restricted in any way (other than by the overarching rules of the forums, such as decency), but posters are expected to discuss something related to the respected character class in some way, whether that be anecdotes, strategies, complaints, preferences, or what have you. We pulled a random sample of 1,984 posts across 85 threads of 4,656 threads total ($\overline{X} = 23$, $\sigma = 38$ posts per thread), resulting in a confidence level of approximately 91%. Data from the discussion forums were saved as text files, extraneous information and HTML markup tags were removed, and descriptive information (such as data on the "level" of each poster) was collected in a separate spreadsheet. The final corpus included discussion posts made by 1,087 unique *WoW* characters.

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 (following methods outlined in Chi 1997) based in combination on a subset of the AAAS benchmarks for scientific literacy (American Association for the Advancement of Science 1993), Chinn and Malhotra's (2002) theoretical framework for evaluating inquiry tasks, and Kuhn's (1992) framework for categorizing epistemological stances in argumentation. Both the AAAS benchmarks and the Chinn and Malhotra report have been quite influential in science education, with the former serving as the basis of the National Research Council's (1996) Science Standards and many state science standards for K-12 education in the United States. Kuhn's work has also proven quite influential in its own right in research on argumentation in informal scientific reasoning. 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), previous games related literature (Gee 2003; Squire 2003, 2005; Steinkuehler 2004, 2005, 2006a, 2006b, 2006c), and a pilot study conducted in preparation for this investigation (Steinkuehler and Chmiel 2006).

Our goal was to focus on scientific reasoning as "the building of houses" rather than the "collection of stones," per the vision of science practice articulated by Poincaré (1905/2001) and science education forwarded by Dewey

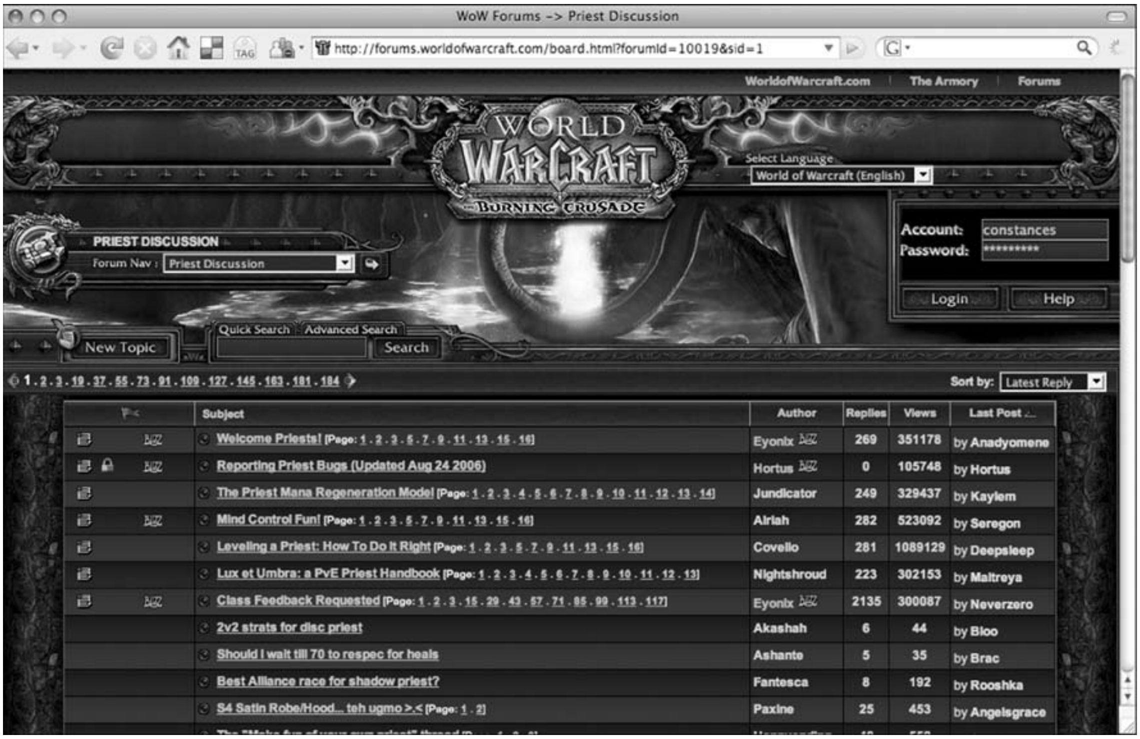

Fig. 1 The priest class forum sponsored by Blizzard

(1910) and Schwab (1962). Therefore, important aspects to scientific understanding that are specific to *content knowledge* rather than practice per se (e.g. an understanding of natural forces) are notably absent. However, given the focus of our interests (scientific practices rather than content) and the nature of the phenomenon under investigation (a simulated world that makes no claims of correspondence with the natural one), such omission was justified. Table 1 includes the full set of 18 codes and their definitions.

Together, the coding set addresses aspects of scientific thinking as seen through three major groups of codes: Scientific discursive practices (including social knowledge construction), systems- and model-based reasoning, and tacit epistemologies. The scientific discursive practices codes each addressed a different aspect of argumentation, discourse, and the use of evidence or other resources in the formulation of an argument. The systems- and model-based reasoning codes each addressed a different aspect of scientific thinking, cutting across specific scientific domains, including reasoning using systems and models; understanding feedback, prediction and testing; and the use of mathematics to investigate the problem under discussion. Finally, the tacit epistemology codes addressed the implicit conception of knowledge employed by an author in a given post—that knowledge is objective and absolute, or that it is subjective and nothing is certain, or that knowledge is shaped through evaluation and argument. Four raters, each of whom had at least 4 months of experience as participant observer within the game, coded the data; four-way interrater reliability, calculated on a subset of roughly 10% of the corpus, was 92%.

In addition, a second set of codes were developed in order to characterize the *WoW*-specific content discussed in each post. Two raters, both with over a year of participant-observer experience within the game, coded the data; two-way interrater reliability, calculated again on roughly 10% of the corpus, was 93%. Additionally, for each poster, we collected virtual "demographic" information—including character level, race, class, guild status, and player-vs.-player rank—in addition to the total number of occurrences of each scientific reasoning and content code their posts received and the total number of posts per individual made.

Findings

The results from this analysis are presented in Fig. 2, which shows the percentage of posts that exhibit each code we focused on for analysis. Here, we see the saturation of key characteristics of scientific reasoning skills and dispositions across the sample. Several interesting patterns emerge from this analysis.

Table 1 The full set of analytic codes used to assess scientific habits of mind

Scientific discursive practices	
Social knowledge construction	Scientists construct knowledge in collaborative groups; students do not (AAAS.D.12.6 & 1.A.12.2; Chinn and Malhotra 2002)
Build on others' ideas	Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration (AAAS)
Use of counter-arguments	Suggest alternative claims or arguments, criticize arguments in which data, explanations, or conclusions are represented as the only ones worth consideration with no mention of other possibilities, suggest alternative trade-offs in decisions and designs, criticize designs in which major trade-offs are not acknowledged (AAAS.12.E)
Uses data/evidence	Use data or evidence in making arguments and claims (AAAS)
Alternative explanations of data	No matter how well one theory fits observations, a new theory might fit them just as well or better, or might fit a wider range of observations. In science, the testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world but not to absolute truth (AAAS.1.A.12.3, AAAS.12.A.8.3)
References outside resources	References outside resources in making arguments and claims (e.g., other threads or stickies, online articles, databases) (AAAS12.D.8.3/Chinn and Malhotra 2002)
Systems and model based reasoning	
Systems based reasoning	Reasons about some phenomenon or problem in terms of a system—a collection of components and processes that interact in some way (ie. have relationships to one another of some form). Defined systems have boundaries, subsystems, relation to other systems, and inputs & outputs (AAAS.11.A)
Understanding feedback	Thinking about things as systems means looking for how its components relate to each other. Output from one parts of a system can function as input to other parts of a system. A change in one component's state can result in changes in another component's state. This includes relationships among components within a system or between systems (AAAS.11.A.8.2)
Model based reasoning	Model-based reasoning involves the envisionment of a principle-based mechanism with interacting components that represents the operation of system within the natural (virtual) world. A model may concretize phenomena that are not directly observable (Mayer 1992; AAAS.11.B)
Model testing and prediction	The usefulness of a model can be tested by comparing its predictions to actual observations in the real world. But a close match does not necessarily mean that the model is the only "true" model of the only one that would work (AAAS.11.B.12.2)
Mathematical modeling	The basic idea of mathematical modeling is to find a mathematical relationship (e.g. algebraic equation, relationship between two quantities, etc) that behaves in the same ways as the objects or processes under investigation. A mathematical model may give insight about how something really works or may fit observations very well without any intuitive meaning (AAAS.11.B.12.1)
Mathematical computation	Explicitly gives some form of mathematical calculation in their argument or thesis that is not given by the game itself (e.g., not merely the DPS listed on a weapon). For example, demonstrates how an algebraic equation (a mathematical model) can be solved for (or predict) the relative trade off between two variables, or compares two groups using their mean, median, variance, standard deviation, etc (AAAS.12.B)
Not relevant to sci reason	Social banter, non science related topics, etc
Uncodable	Cannot tell if it is science related or not
Tacit epistemologies	
Absolutist	Knowledge is objective, certain, and simply accumulates (Kuhn 1992)
Relativist	Knowledge is subjective, dictated only by personal tastes and wishes of the knower. Nothing is certain, all opinions are of equal validity, and even experts disagree (Kuhn 1992)
Evaluative	Knowledge is an open-ended process of evaluation and argument (Kuhn 1992)
Uncodable	Cannot tell what epistemology the poster tacitly holds

Social Knowledge Construction

The first and most obvious pattern is the large proportion of productive discussion found on the boards: We found that 86% of the *WoW* discussion forums consisted of talk that could be considered "social knowledge construction"—meaning, the collective development of understanding, often through joint problems solving and argumentation. In other words, in the overwhelming majority of forum talk, participants were solving problems through discussion, knowledge sharing, and debate through threads that began with posts such as "I notice that high level priests carry

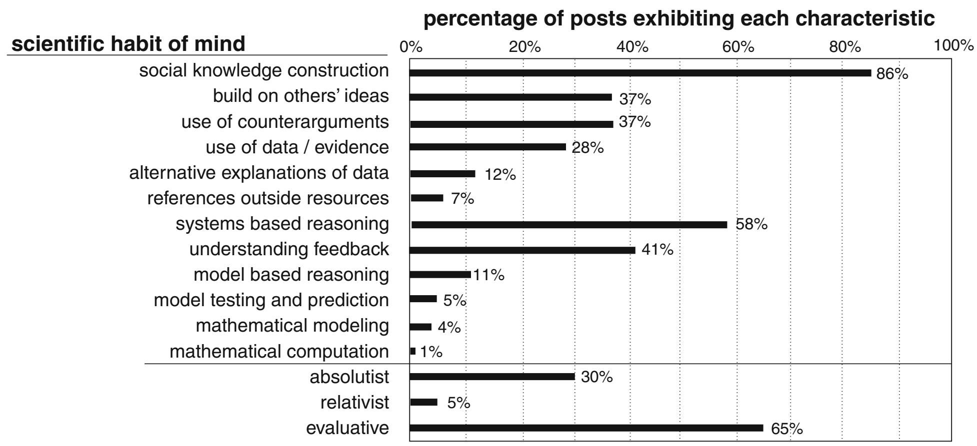

Fig. 2 Proportion of posts within the data corpus that exhibit each scientific habit of mind and tacit epistemology under examination

around a great deal of potions… Which potions do you carry around constantly and why?" (post #3357.0) Only 8% of the discussion posts were mere social banter (the remaining 6% were uncodable with this coding scheme)—perhaps a surprising result for those who presume that discussions around videogames are a "torpid" waste of time.

One of our initial hypotheses was that only the more experienced *WoW* players would engage in higher order intellectual work on the discussion forums. In fact, we found no relationship between a given poster's character level (which represents their experience with the game) and the quality or quantity of the attributes for which we coded, other than a very mild and negative correlation ($r = -0.08$) between author's character level and social banter. Thus, while we cannot disprove the notion that only the "hardcore" gamers engage in the forms of informal science literacy investigated here, we find no evidence that such is indeed the case.

Scientific Discursive Practices

Of the 86% of the forum posts that were not social banter or simply uncodable, roughly one third (37%) built on ideas that previous posters had raised; for example, by stating "Given your advice, I've spec'd out the following talents…" (post #4109.29). Roughly another third (37%) used counterarguments against previous posters' ideas; for example, stating "The real question is 'Are Holy or Disc priests going to kill as much?' And the answer is no. Shadow has more offensive utility, which is just as important as the increase in damage…." (post #2143.5) That *WoW* players either elaborated on or disagreed with previous people's comments in the context of a forum should come as no surprise given the "collectively intelligent" (Levy 1999) nature of many such communities. However, it is interesting that forms of *scientific* argumentation were also prevalent within this informal context, given previous findings indicating that such practices do not come naturally and are difficult to foster (Kuhn 1992; Osborne et al. 2004).

As another illustration of scientific argumentation, in 28% of the posts made individuals used data or evidence of some form in order to warrant their claims. For example, in a thread discussing priest healing strategies, one poster argues for his strategy by stating, "my +355 healing allows me to use Heal4 [spell] to hit around 1k+ every time, ignoring crits [critical hits]. That's good enough to spam [cast repeatedly] for most battles while throwing in a Fheal [flash heal] now and then" (post #3247.20). In another 12%, individuals challenge one another's hypotheses by providing alternative explanations of evidence used to support those suppositions with statements such as the following:

> The calculations correctly show that mind flay [spell] receives just as much +damage percentage as mind blast. However mind blast has a 1.5 second cast time, and mind flay has a 3 second cast time. And therefore mind flay receives half the dps [damage per second] boost it should. (post #2609.43)

And in 7% of the posts, participants cited a variety of information resources beyond the current discussion thread itself (see Table 2). For example, one poster: recommended a particular character configuration (i.e. "talent build," discussed below) over another with the statement "I would be more inclined to go with a build similar to: http://www.wowhead.com/?talent=bVMhzZZx0gtczR if you would like to go Shadow [one particular form of character specialization]" (post #3374.9).

What did the typical "social knowledge construction" discussion thread containing "scientific discursive practices" look like? As the example in Fig. 3 illustrates, most such discussions began with an initial question about a given

Table 2 Types of outside resources referenced by forum posters within the sample

	Outside resources referenced
Talent calculators/ builds	Links to an official or unofficial tools for calculating talent point allocations
Personal talent builds	Links to a player's specific talent build
WoW databases and Wikis	Links to information on publicly accessible *WoW* databases and Wikis created by *WoW* players themselves
Official blizzard documents	Links to official information published by Blizzard
Other *WoW* forums	Links to other discussions in the *WoW* forums (beyond current forum)
Personal websites	Links to a player's personal website or other online material

mechanic in the game or game-playing strategy, often coupled with the proposal of some theory. A second poster would typically then elaborate in answering the question or responding to the proposed theory, at times using data from the game to warrant the claims made. The response would then be discussed and debated by a larger group. Often a second, alternative hypothesis or explanation would eventually be offered (or, more rarely, the interpretation of the data used in the first explanation was reinterpreted), followed by an additional round of discussion and debate, and so on. Occasionally, confirming or disconfirming claims or evidence from other resources, such as collaborative online manuals to the game (e.g. WoWWiki, http://wowwiki.com) or other archived discussions on this or other forums, would be introduced into the discussion. In some threads, a comparison or synthesis of the two or more explanations would culminate the discussion; in others, the conversation simply petered out as though the participants had accepted the most recently posted theory or explanation as the preferred one or had perhaps tired of the topic and moved on.

System- and Model-Based Reasoning

Over half (58%) of the *WoW* forum posts evinced *systems based reasoning*, the majority of which also demonstrate an understanding of feedback among components of the system. For example, participants discussed the game in terms of components and processes that interact in ways such that changes in one impact cause changes in another, as in the following post:

> By choosing a slower spell [variable one] and the lowest rank [variable two] you can live comfortably with (or your tank can live with, in our case), you are still making the most of your mana [variable three], given your gear [variable four]. (post #3247.12)

Roughly one tenth of the forum posts illustrated *model-based reasoning*—essentially, using some form of model to understand a given system under consideration—with about half of those (5% of posts total) including some comparison between the model's predictions and actual observations of the phenomenon it is intended to capture or explain in some way. One example of such discussion focused on a phenomenon called "scaling." Imagine that, for a level 2 priest, a given spell does 10 damage; when the priest reaches to level 20, that 10 damage accomplishes much less because the level 20 priest is now fighting much harder monsters. In order to balance ability with challenge, *WoW* makes higher level, stronger spells available as one's character level increases. In place of a spell that does 10 damage would be a spell that does 100 damage, for example, so that the ability to do damage to monsters using a given spell "scales" as character level increases. Scaling is not the same for every spell or character class, and one way that designers "balance" their game mechanics is to monitor and tweak scaling. In the following excerpt, a participant proposes one particular model of how the in-game scaling mechanics work and considers that model's predictions given changes in input:

> "If mind flay [priest spell] actually got the full scaling of a 3 second cast spell, then by combining mind flay with both dots [priest damage over time spells] and all available talents [point system for specializing character types] to improve those, you would actually see a shadow priest's scaling maxing out at a little under 80% of what a fire mage's scaling would max out at with 40 fire and nothing more." (post #2609.51)

Thus, posters orient toward the usefulness of a model in terms if its ability (or inability) to make predictions that match actual observations. Slightly less than half of those models (4% of posts total) were explicitly mathematical, and only 1% of the total forum posts included actual computations as well. An example illustrating both is the following post excerpt raising issues about the balance of priest versus mage abilities:

> By intuition, you should notice a problem…
> but I'll give you the numbers anyways
> For Mindflay, SW:P, and presumpably VT [3 priest spells]:
> Damage = (base_spell_damage + modifier * damage_gear) * darkness * weaving * shadowform * misery
> For Frostbolt [mage spell]
> Average Damage = (base_spell_damage + (modifier + empowered frost) * damage_gear) * (1 * (1 − critrate − winter's chill − empowered frost) +

scientific habit of mind

post#	social knowledge construction	build on others' ideas	use of counterarguments	use of data / evidence	alternative explanations of data	references outside resources	systems based reasoning	understanding feedback	model based reasoning	model testing and prediction	mathematical modeling	mathematical computation	absolutist	relativist	evaluative
0 Poses question: group healing strategy (A) or (B)?	●			●			●	●	●						●
1 Advocates (B) & gives strategy (C)	●				●		●	●							●
2 Compares (A) & (B) on use conditions, advocates (A)	●													●	
3 Critiques (A) & (B), advocates (C), raise issue (X)	●	●	●				●	●							●
4 Elaborates (X)	●	●		●			●	●							●
5 Elaborates (X)	●	●			●		●	●					●		
6 Argues (A) > (B)	●	●	●				●	●							●
7 Elaborates (X)	●	●					●	●					●		
8 Elaborates (A) > (B) but dependent on conditions	●	●					●	●						●	
9 Argues (A) = (B) under the right conditions for each	●	●	●		●		●	●						●	
10 Counterargues (B) > (A)	●	●	●	●			●	●					●		
11 Elaborates counterargument (B) > (A)	●	●	●	●	●		●	●	●	●	●		●		
12 Details scenario with (B) strategy & issue (X)	●		●				●	●	●						●
13 Details scenario with both (A) & (B) strategies	●		●	●			●	●	●						●
14 Details scenario with (A) strategy & new issue (Y)	●		●												●
15 Challenges detail of scenario with (A)	●	●													
16 Argues (A) > (B)	●		●	●			●	●							●
17 Argues (B) > (A) & details issue (X)	●	●	●	●			●	●	●					●	
18 Elaborates (A) > (B)	●	●					●								
19 Counterargues (B) > (A)	●	●													●
20 Argues (B) > (A)	●		●				●	●							●
21 Compares (A) & (B) on use conditions, advocates (A)	●		●	●	●		●	●							●
22 Original poster acknowledges discussion	●														●
23 Argues both (A) & (B) strategies	●						●	●							●
24 Argues (A) > (B)	●			●			●	●						●	
25 Counterargues (B) > (A)	●		●	●			●	●							●
26 Argues (A) = (B) under right conditions based on (X)	●	●	●	●	●		●	●	●						●
27 Details scenario w/ (A) & (B) & (C) strategies given (X)	●		●				●	●	●						●
28 Argues (A) > (B)	●		●	●											
29 Argues (A) = (B) under right conditions based on (X)	●			●			●	●	●						●
30 Elaborates detail of scenario with (A) & (B) & (C)	●						●	●							
31 Counterargues (B) > (A)	●	●	●	●			●	●	●	●	●				●
32 Argues (B) > (A)	●			●			●	●							●
33 Challenges initial characterization of (B)	●												●		
34 Argues (A) > (B) & raises issue (X)	●		●	●			●	●	●				●		
35 Argues (A) > (B)	●		●	●						●	●		●		
36 Details scenario with both (A) & (B) strategies	●		●	●			●	●	●				●		

A = spam PoH
B = Holy Nova
C = renew

X = FR gear
Y = FR pots

Fig. 3 An example "social knowledge construction" thread (# 329) of 36 posts detailed in terms of both the argumentative moves made within each and the codes applied to them

> (1.5 + ice shards) * (critrate + winter's chill + empowered frost)) * piercing ice
> mindflay = (426 + 0.45 * dam) * 1.1 * 1.15 * 1.15 * 1.05
> 650.7 + 0.687 * dam
> frostbolt = (530 + (0.814 + 0.10)*dam) * ((1 − crit − 0.10 − 0.05) + (1.5 + 0.5) * (crit + 0.10 + 0.05)) * 1.06
> (530 + 0.914 * dam) * ((0.85 − crit) + 2 * (crit + 0.15)) * 1.06
> 0.968 * (dam + 579.7) * (crit + 1.15)
> Please notice the 0.687 versus the 0.968. That's the scaling factor. (post #2609.18)

In this example, the author makes an argument about the relative scaling of priest skills compared to mage skills based on a thoroughly mathematical argument, using computation as a form of evidence for the points made. His conclusion—that the scaling factor of each class type (0.687 and 0.968 respectfully) is unequal—is his climactic justification for the initial claim that the two character classes are not balanced.

What did a typical "systems- and model-based reasoning" forum post discussion thread look like? Fig. 4 shows the analysis of one post-containing relevant codes.

Typically, such posts would occur in context of broader "social knowledge construction" threads (described above). In order to make an argument for one particular hypothesis or solution for some in-game system, the poster would often present a model to explain the system as evidence for their claim. In some rare cases, that model would be mathematical in nature, and fidelity between the model's prediction and actual in-game observations would function as evidence of its explanatory power. More frequently, evidence would include direct observations taken in-game and references to outside resources such as collective data sets, heuristics in the form of online database backed websites, or fan-created user manuals and guides. Generally speaking, the proportion of model-based reasoning, model testing and prediction, use of mathematics, and explicit computation (11%, 5%, 4%, 1%, respectively) were rather low; however, the sophistication of arguments that leverage such models warrants consideration. For example, Fig. 5 shows the model linked in the post detailed in Fig. 4.

Tacit Epistemologies

We chose to examine the dispositions toward knowledge exhibited in the data corpus because previous pilot work

social knowledge construction	**The unfortunate fact is that there is no shadow nuke [prior topic]**... and no shadow nuke which benefits from reduced casting time. All other casters (including holy priests) have a nuke which benefits from reduced casting time: bane, improved fireball, improved frostbolt, divine fury,
uses data/evidence	improved wrath. I have put together **my own spreadsheet** which goes into more detail and takes into account exactly what happens to **spells**
systems based reasoning **understanding feedback**	**with regard to talents** and gives a column at the end expressing **each spell's total scaling with respect to +dmg [damage] applied per second** (i.e. how much your gear actually improves your dps):
model based reasoning **mathematical modeling** **mathematical computation**	**http://geocities.com/[omitted].htm** →
references outside resources **evaluative epistemology**	If I got anything wrong feel free to email me at [omitted]@gmail.com but if you read up at **wowwiki.com** and check out the **coefficients used in the theorycraft mod** you'll find that I'm consistent with respect to them.
model testing & prediction	You see there at the end - if you add flay and swp together you see that shadow is at 31%, where fire mages are around 48%. I have done some preliminary numbers for the expansion and shadow only improves to 35% as fire mages jump way up to 60%. **If flay were empowered to the point that it recieved 65% of +dmg then shadow would be up around 45% dps scaling.** That would be quite respectible considering that a shadow priest can swp/flay for nearly 2 minutes without interruption where other classes would peter out in a minute or less except for their mana recovery abilities. Without empowered scaling shadow priests will languish at under 50% of the endgame dps of mages and warlocks. (post #2609.6)

Fig. 4 Analysis of an individual post exemplifying system- and model-based reasoning

Constants:																	Crit Rate	5%		
Class	Spec	Spell (+ talent conditions)	Spell Damage Scale	Damage Talents	Target Debuffs	Damage Scale	Spell Damage Total Scale	Crit Bonus	Crit Rate Bonus	Crit Scale	Damage Interval	Cast Interval	Cast Time	Casts Per Interval	DPS Scale	Time Ratio	Max Crit DPS Scale	Modified Crit Rate	TOTAL DPS SCALE	Notes
			Cast Time / 3.5	per talents	per abilities	talents * debuffs	scale * talents * debuffs	per talents (no bennefit for dots)	per talents	total scale * crit bonus	limited by dots	limited by cooldowns			total scale / dmg interval	dmg interval * cast interval / # casts	crit scale / dmg interval	crit rate + rate bonus	dps * (1 - crit rate) + crit dps * crit rate	
Solo Caster Classes at Level 60																				
Priest	Shadow	Mind Flay	45.7%	125%	115%	144%	65.7%	100%	0%	65.7%	3	3	Channel	1	21.90%	100.00%	21.90%	5.00%	21.90%	Channeled
		SWP	133.3%	125%	115%	144%	191.7%	100%	0%	191.7%	18	18	1.5	1	10.65%	100.00%	10.65%	5.00%	10.65%	
		Mind Blast	42.9%	125%	115%	144%	61.6%	150%	0%	92.4%	1.5	5.5	1.5	1	41.07%	27.27%	61.61%	5.00%	42.10%	
	Disc/Holy	Smite	71.4%	115%	100%	115%	82.1%	150%	15%	123.2%	2	2	2	1	41.07%	100.00%	61.61%	20.00%	45.18%	
		Holy Fire	75.0%	115%	100%	115%	86.3%	150%	15%	129.4%	3	3	3	1	28.75%	100.00%	43.13%	20.00%	31.63%	Dot
		Holy Fire Dot	25.0%	115%	100%	115%	28.8%	100%	15%	28.8%	10	10	3	1	2.88%	100.00%	2.88%	20.00%	2.88%	
		SWP	100.0%	105%	100%	105%	105.0%	100%	0%	105.0%	18	18	1.5	1	5.83%	100.00%	5.83%	5.00%	5.83%	
		PI + Smite	71.4%	135%	100%	135%	96.4%	150%	15%	144.6%	2	180	2	6	48.21%	6.67%	72.32%	20.00%	53.04%	Cooldown
		PI + Holy Fire	75.0%	135%	100%	135%	101.3%	150%	15%	151.9%	3	180	3	5	33.75%	8.33%	50.63%	20.00%	37.13%	Dot + Cooldown
		PI Holy Fire Dot	25.0%	135%	100%	135%	33.8%	100%	15%	33.8%	10	180	3	2	3.38%	11.11%	3.38%	20.00%	3.38%	
Warlock	SM/Ruin	Shadowbolt	85.7%	110%	110%	121%	103.7%	200%	5%	207.4%	2.5	2.5	2.5	1	41.49%	100.00%	82.97%	10.00%	45.63%	
		Corrumption	100.0%	110%	110%	121%	121.0%	100%	0%	121.0%	18	18	1.5	1	6.72%	100.00%	6.72%	5.00%	6.72%	
		Curse of Agony	100.0%	110%	110%	121%	121.0%	100%	0%	121.0%	24	24	1.5	1	5.04%	100.00%	5.04%	5.00%	5.04%	improved CoA does not apply to gear
		Shadowburn	42.9%	110%	110%	121%	51.9%	200%	5%	103.7%	1.5	10	1.5	1	34.57%	15.00%	69.14%	10.00%	38.03%	
		Improved Shaodwbolt	85.7%	110%	132%	145%	124.5%	200%	5%	248.9%	2.5	2.5	2.5	1	49.78%	100.00%	99.57%	10.00%	54.76%	Luck
	SM/DS	Shadowbolt	100.0%	125%	110%	138%	137.5%	150%	0%	206.3%	3	3	3	1	45.83%	100.00%	68.75%	5.00%	46.98%	
		Corruption	100.0%	125%	110%	138%	137.5%	100%	0%	137.5%	18	18	1.5	1	7.64%	100.00%	7.64%	5.00%	7.64%	
		Curse of Agony	100.0%	131%	110%	144%	144.1%	100%	0%	144.1%	24	24	1.5	1	6.00%	100.00%	6.00%	5.00%	6.00%	
	Ember/DS	Soul Fire	100.0%	125%	110%	138%	137.5%	200%	5%	275.0%	6	6	6	1	22.92%	100.00%	45.83%	10.00%	25.21%	Reagent
		Searing Pain	42.9%	125%	110%	138%	58.9%	200%	15%	117.9%	1.5	1.5	1.5	1	39.29%	100.00%	78.57%	20.00%	47.14%	
		Immolate	19.8%	150%	110%	165%	32.7%	200%	5%	65.3%	1.5	1.5	1.5	1	21.78%	100.00%	43.56%	10.00%	23.96%	Dot
		Immolate Dot	65.3%	125%	110%	138%	89.8%	100%	5%	89.8%	15	15	1.5	1	5.99%	100.00%	5.99%	10.00%	5.99%	
	MD/Ruin	Shadowbolt	85.7%	115%	110%	127%	108.4%	200%	5%	216.9%	2.5	2.5	2.5	1	43.37%	100.00%	86.74%	10.00%	47.71%	
		Corrumption	100.0%	115%	110%	127%	126.5%	100%	0%	126.5%	18	18	1.5	1	7.03%	100.00%	7.03%	5.00%	7.03%	
		Curse of Agony	100.0%	115%	110%	127%	126.5%	100%	0%	126.5%	24	24	1.5	1	5.27%	100.00%	5.27%	5.00%	5.27%	improved CoA does not apply to gear
		Shadowburn	42.9%	115%	110%	127%	54.2%	200%	5%	108.4%	1.5	10	1.5	1	36.14%	15.00%	72.29%	10.00%	39.76%	
		Improved Shaodwbolt	85.7%	115%	132%	152%	130.1%	200%	5%	260.2%	2.5	2.5	2.5	1	52.05%	100.00%	104.09%	10.00%	57.25%	Luck
Mage	Frost	Frostbolt	81.4%	106%	100%	106%	86.3%	200%	10%	172.6%	2.5	2.5	2.5	1	34.53%	100.00%	69.05%	15.00%	39.70%	winter's chill for all ice
		Frozen + Frostbolt	81.4%	106%	100%	106%	86.3%	200%	60%	172.6%	2.5	2.5	2.5	1	34.53%	100.00%	69.05%	65.00%	56.97%	Frozen target
	AP/Frost	Frostbolt	81.4%	109%	100%	109%	88.8%	200%	3%	177.5%	2.5	2.5	2.5	1	35.50%	100.00%	71.01%	8.00%	38.34%	
		Frozen + Frostbolt	81.4%	109%	100%	109%	88.8%	200%	63%	177.5%	2.5	2.5	2.5	1	35.50%	100.00%	71.01%	68.00%	59.64%	Frozen target
		AP + Frostbolt	81.4%	139%	100%	139%	113.2%	200%	3%	226.4%	2.5	180	2.5	5	45.27%	6.94%	90.55%	8.00%	48.90%	Cooldown
		AP + Frozen Frostbolt	81.4%	139%	100%	139%	113.2%	200%	63%	226.4%	2.5	180	2.5	5	45.27%	6.94%	90.55%	68.00%	76.06%	Cooldown + Frozen target
	Fire	Fireball	100.0%	110%	115%	127%	126.5%	219%	6%	277.0%	3	3	3	1	42.17%	100.00%	92.35%	11.00%	47.69%	imp scorch for all fire mage
		Fire Blast	42.9%	110%	115%	127%	54.2%	219%	10%	118.7%	1.5	8	1.5	1	36.14%	18.75%	79.15%	15.00%	42.59%	ignite is 150% + 150% * 40% * debuffs
		Scorch	42.9%	110%	115%	127%	54.2%	219%	10%	118.7%	1.5	1.5	1.5	1	36.14%	100.00%	79.15%	15.00%	42.59%	
	AP/Fire	Fireball	100.0%	103%	115%	118%	118.5%	219%	6%	259.4%	3	3	3	1	39.48%	100.00%	86.47%	11.00%	44.65%	
		Scorch	42.9%	103%	115%	118%	50.8%	219%	6%	111.2%	1.5	1.5	1.5	1	33.84%	100.00%	74.12%	11.00%	38.27%	
		AP + Fireball	100.0%	133%	115%	153%	153.0%	219%	6%	335.0%	3	180	3	4	50.98%	6.67%	111.65%	11.00%	57.66%	Cooldown
Druid	Balance	Moonfire	20.0%	110%	100%	110%	22.0%	200%	13%	44.0%	1.5	1.5	1.5	1	14.67%	100.00%	29.33%	18.00%	17.31%	Dot, imp MF doesn't apply to gear
			57.1%	110%	100%	110%	62.9%	100%	13%	62.9%	12	12	1.5	1	5.24%	100.00%	5.24%	18.00%	5.24%	
		Wrath	57.1%	110%	100%	110%	62.9%	200%	3%	125.7%	1.5	1.5	1.5	1	41.90%	100.00%	83.81%	8.00%	45.26%	
		Starfire	100.0%	110%	100%	110%	110.0%	200%	3%	220.0%	3	3	3	1	36.67%	100.00%	73.33%	8.00%	39.60%	
Shaman	Elemental	Lightning Bolt	85.7%	105%	100%	105%	90.0%	200%	10%	180.0%	2	2	2	1	45.00%	100.00%	90.00%	15.00%	51.75%	
		Chain Lightning	71.4%	105%	100%	105%	75.0%	200%	10%	150.0%	1.5	6	1.5	1	50.00%	25.00%	100.00%	15.00%	57.50%	

Fig. 5 An example model of an in-game phenomenon called scaling (Basic n.d.) that illustrates the complexity of the models sometimes discussed

indicated that, while we may find informal science reasoning and argumentation in *WoW* forum discussions, it may also be the case that the stance authors in such contexts take toward their claims is appropriate for *reverse engineering,* but inappropriate for *scientific inquiry* (Steinkuehler and Chmiel 2006). An "absolutist" epistemology, for example, might serve someone well when operating in a virtual world where there really is a single algorithm (or set of algorithms) underlying a given phenomenon and success is only a matter of finding them. However, such an absolutist approach does not serve someone well for understanding science in the real world. Instead, in science, an evaluative disposition is most appropriate, one that treats knowledge as an open-ended process of evaluation and argument of hypotheses about whether and how "algorithms" govern natural phenomena.

The epistemology tacitly displayed in 27% of the data corpus was too ambiguous to code. Of the remaining data corpus that could be coded for epistemological disposition, we found that 65% of the forum posts displayed an evaluative epistemology through rhetorical moves that treat knowledge as an open-ended process of evaluation and argument such as "Shadow Affinity [priest talent] and Silent Resolve[priest talent]: Do they stack? If so, why would a shadow priest need a 45% reduction in threat?" (post #1937.0). Thirty percent displayed an absolutist epistemology, treating knowledge as objective, certain, and simply accumulative through statements such as: "There is a basic strategy for any one class vs any other class and whoever carries out that strategy most successfully will win" (post #415.92) [even though no such basic strategy exists]. Another 5% displayed a relativist epistemology, treating claims about the world as subjective and "to each his own" (post #215.58). Thus, the majority of posts that could be coded in terms of the attitude toward knowledge held fell into the "evaluative" category, which is consistent with scientific inquiry and inconsistent with reverse engineering. We discuss these findings in greater depth below.

Game Specific Content

What specific content areas of the game elicit these forms of informal science literacy practice? Examining the relationships among our scientific habits of mind codes (see Table 1) and our *WoW* content codes (Table 3), we found that the only moderately strong and non-obvious relationship between the two was between systems-based reasoning (and its concomitant "understanding feedback") and discussion of the priest "talent tree" ($r = 0.48$ and 0.42, respectively), shown in Fig. 6, whereby players allocate "talent points" toward customizing the functions and abilities of their online character or "avatar."

In working through this system, 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). Because *WoW* is a complex system with no single obvious solution, a significant amount of time on the priest discussion boards is spent assessing how choices in one area of the talent tree affect outcomes elsewhere and debating which point allocations are best given various play styles and goals. Many of the examples used throughout this paper are a testament to the intellectual labor spent on just this one game-related content area.

Discussion and Implications

Our goal has been to provide empirical evidence to substantiate claims of the potential of MMOs as sites fostering learning, especially informal science literacy. Given the overall representativeness of our sample (confidence level of 91%), we are in a good position to make reasonably strong claims. Overwhelmingly, game related forums like the one examined here are rich sites for social knowledge

Table 3 A second set codes used to describe the game-related content of the post

World of Warcraft content codes		
Guilds	Items, equipment, supplies	PvP content, battlegrounds
Quests, instances, raids	Talent trees, spells, abilities	Collaborative play
Other classes (than priests)	Addons, macros	Patches, expansions
Factions (horde vs. alliance)	*WoW* forums, trolling	Class/profession guides, how-to's
Reputation/experience grinding, leveling	Null/social banter	Uncodable

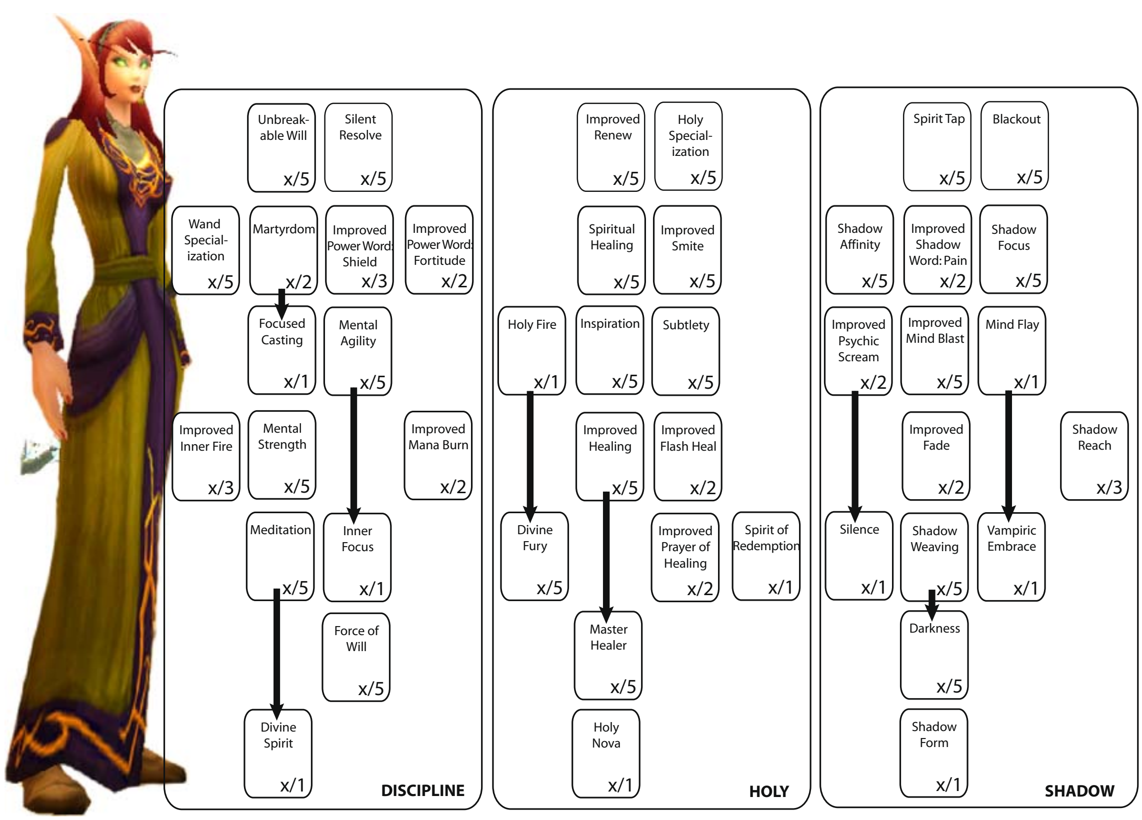

Fig. 6 The *World of Warcraft* "talent tree" for the priest class (at the time of data collection), which enables players to customize their avatars

construction. That game communities engage in productive forms of discussion and problem solving is not surprising; that such an overwhelming majority of their conversation (86%) is dedicated to such labor *is* surprising. Discursive practices include argument, counterargument, and the use of evidence to warrant one's claims. In such contexts, much of the conversation focuses on puzzling through complex systems within the virtual world and the relationships among components within those systems. At times, that inquiry includes the proposal of explanatory models of how the system under scrutiny functions. On rare occasions, posts debate the merits of their models in terms of their predictive power. On even rarer occasions still, those models take the form of mathematical equations whose computations are done explicitly and publicly.

The findings on tacit epistemology displayed throughout the discussions were also a surprise. Contrary to our initial hypotheses, the predominant epistemological disposition exhibited in the forum posts was "evaluative" and therefore appropriate to science. Such findings are quite encouraging. In an earlier study of argumentative reasoning in everyday contexts that examined Americans across gender, age, class, and educational level (Kuhn 1992), only 15% of those interviewed held an evaluative epistemology, 50% held an absolutist epistemology, and 35% held a relativist epistemology. In this earlier study, argumentative ability did not differ systematically as a function of gender or age but it did differ systematically in terms of level of education. Kuhn therefore concluded that classrooms are one promising context for the development of such skills. However, she also points out the limitations of teacher led dialogues, crediting the positive impact education has on such attributes to the "social environment of peers" that school, as a byproduct, enables rather than teacher led formal dialogues per se:

> … does school experience in fact offer the opportunity for the kinds of exchange of ideas and argumentative discourse that would enhance development of argumentative thinking? In one sense, the answer is yes; in another sense it is no. The answer is yes in the sense that from the earliest years, schooling provides a social environment of peers. In the informal social interaction that is a major part of school experience, ideas are tested and inevitably challenged; thus social experience serves as the natural challenge to individual thought. In a second deeper sense, however, the answer is no; schools do not provide this opportunity, or at least do not provide it optimally… Even in the best schools, what may appear to be genuine group debates about an issue are usually heavily controlled by the teacher… [who] already possesses the understanding of an issue that he or she wishes students to attain… Most often missing, even in the best of such "discovery-based" pedagogies, is genuine, open debate of complex, unanswered questions." (Kuhn 1992, pp. 175–176).

While Kuhn does not advocate the use of informal social dialogue necessarily either (in her own words, they "only occasionally leads students to think explicitly about their ideas—to reflect on their own thought" p. 175), these data suggest their efficacy, at least under certain conditions. In the context of game related forums, informal social dialogues are indeed "genuine, open debate of complex, unanswered questions" and therefore may very well lead participants toward a more reflective stance toward knowledge ultimately. Such a hypothesis is certainly worth future consideration in studies that follow. Of course, one could also argue that game forums (like the one studied here) tend to attract individuals with a more nuanced stance toward knowledge rather than fostering such a stance themselves. Regardless, we can at least say that the cultural norms that emerge in this part of *WoW* fandom preference an evaluative epistemology and that this preferencing of an evaluative disposition varies significantly from the disposition preferenced by other cultural norms, including but certainly not limited to the typical cultural norms of an American classroom.

In addition providing empirical evidence to substantiate the potential of such play contexts for informal science literacy learning, this study sheds some curious light on the nature of collective intelligence (Levy 1999). Discussion environments such as these are best characterized as *collective* rather than *collaborative*. It could have easily been the case that a handful of verbose posters engage in extended dialogue with each other, making it a highly collaborative (albeit small) community of exceptional minds who happen to make their cognition public. This, however, was not at all the pattern we found. Rather, as Fig. 7 shows, the relationship between length of discussion thread and number of players contributing to it strongly linear.

In such contexts, solutions developed by one person are referenced, debated, and built upon by masses of other participants, not merely a handful of designated experts. Thus, a large number of posters each make one or two contributions to the discussion, with the solution to the problem or answer to the inquiry emerging as a result of swarms of thinkers, not a lonely few.

Such findings are useful in that they enable us to more accurately characterize virtual worlds as learning contexts that stretch across both intra-game and extra-game spaces. As our study shows, forms of inquiry within play contexts such as these are *authentic* although *synthetic*: even though the worlds themselves are fantasy, the knowledge building

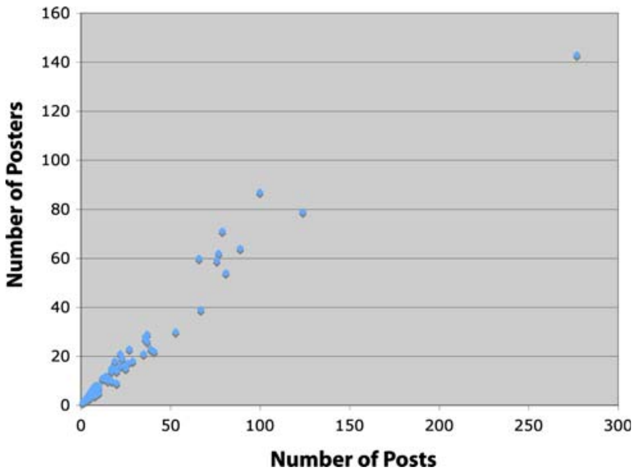

Fig. 7 Scatter plot of number of posts by number of unique posters for each thread in the data corpus

communities around them are quite real. And, it is their designed nature that makes these communities so lively. For they were designed such that particular user-controlled configurations (e.g., how one builds her talent tree) has powerful and important implications for the success of one's game play. In fact, in these synthetic worlds designers can manipulate these dynamics so that they are most likely to breed rich conversations as users struggle with the most appropriate configurations.

What, then, are the implications for science education and future research? There are several. First, the veritable firewall against games and gaming culture within schools might erode. While virtual worlds may seem "torpid" (Solomon 2004) to a non-gaming older generation, empirical analysis of what game communities do and value indicates that this interactive medium might well be a worthy vehicle of learning for those who value intellectual and academic play. In a school system sometimes side-tracked by testing regimes that pressure teachers and students to focus on only a narrow range of topics, popular culture contexts such as these might be a nice complement to classrooms, augmenting classroom instruction by situating informal science literacy in popular culture context.

Second, we should ask ourselves how these practices are distributed across various groups by demographic variables known to be important, such as age, education level, and income. Demonstrating that game communities such as those in *WoW* engage in important forms of science literacy again raises the specter of a new form of digital divide—one not between the have and have-nots, but between the do and do-nots. We need to think deeply about what people are doing with the technologies that are becoming so ubiquitous and engaging. As educators, we have a responsibility to better understand what these different forms of technology afford and communicate this to the public more broadly.

Third and finally, we should actively seek out ways to build *bridging third spaces* (Steinkuehler 2008b) between school and home that incubate forms of academic play such as those studied here. In so doing, we might address both growing digital divides at once. We can ameliorate the generational divide by educating the keepers of the canon as to the genuine merit of games and gaming cultures, and we can close the access gap by providing rich intellectual play spaces in technically and cognitively sophisticated environments to kids and young adults who might not otherwise happen upon them. As Dewey himself once argued, good education, effective and life-enhancing education, represents life "as real and vital to the child as that which he carries on in the home, in the neighborhood, or on the play-ground" (1897).

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