Gamers as Scientists? The Relationship Between Participating in *Foldit* Play and Doing Science

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Abstract: The University of Washington's Center for Game Science (CGS) in collaboration with the Baker Laboratory created a protein-folding game, *Foldit*, which combines computational power and players' ability to recognize patterns to generate innovative solutions to constraining puzzles. Through analysis of public forum data, we consider whether players learned the science of protein structures through playing *Foldit* and participating in its online community and whether players engaged in scientific practice regardless of their understanding of the underlying science. This analysis contributes to understanding how non-traditional, emergent learning environments can support science learning as well as challenge our very definition of what it means to do science, furthering the argument that the practice of science is a mangle, involving many specialized parts that make up the whole machinery of science.

Keywords: Video games, Science education, Situated learning, Foldit, Computer-supported collaborative learning

Released by the University of Washington's Center for Game Science (CGS), the protein-folding game, *Foldit* (http://fold.it/), has received good media attention, such as in *Wired* (Bohannon, 2009), highlighting the use of digital games to help scientific endeavors. The developers at CGS worked with biochemists in The Baker Laboratory to design a game that combines computational power with human ability to quickly recognize patterns and generate innovative solutions to constraining puzzles around protein science. The results have been astounding, resulting in research publications in *Nature* (Cooper et al., 2010; Khatib et al., 2011), featuring thousands of authors, and, more importantly, helping biochemists solve long-standing problems in their field (cf. http://fold.it/portal/node/989576).

While the game was never intended specifically to teach scientific concepts to players, many questions arise about using *Foldit* to teach the concepts and whether *Foldit* can be integrated into classroom curricula. Recognizing and valuing emergent learning that already occurs in informal player communities, however, we approach *Foldit* from a different angle and ask whether players already learn the science behind protein structures through learning the puzzle-based mechanics of the digital game. Furthermore, we ask whether players engage in scientific practice, even if they do not understand the underlying science.

Objectives/Purpose

This paper presents research into the degree in which science learning and/or scientific practice is demonstrated by *Foldit* players. Our research questions include:

- Do *Foldit* players learn scientific concepts behind the game? Does knowing the science help players become better at playing *Foldit*? How does *Foldit* shape the learning that happens around protein science?
- What does the practice of playing *Foldit* look like and how does it map onto scientific practice? Do *Foldit* players engage in scientific practice? How does understanding *Foldit* practice change how we understand what doing science is?
- What kinds of communication happen in and around *Foldit*, and how do these link to the National Research Council's strands of science learning (2009) and framework for classroom science practice (2012) (see below)?

Theoretical and Analytical Framework

Our theoretical approach is grounded in sociocultural views of situated learning (Lave & Wenger, 1991), using discourse analysis (Gee, 1999) and science and technology studies (Latour, 2005; Shrum et al., 2001) informed analytical lenses. Playing a game, particularly a game with built-in social components such as player rankings and in-game chat, elements that *Foldit* includes, means participating in a specific community of practice. This practice includes the use of available sociomaterial resources in an emergent, dynamic system or network of activity (Salen, 2008; Taylor, 2009). Furthermore, like others (Steinkuehler, 2006; Steinkuehler & Duncan, 2008), we argue that play practice and science practice are not dissimilar.

Drawing from the landscape of entertainment and educational games, we outline the unique game-play qualities of *Foldit* as a contributing factor to learning. *Foldit* creates and sustains competitive (high scores and group competitions) and collaborative (sharing "recipes" or scripts and strategies) game play. The type of game (3D manipulation, puzzle-solving) and community support is common for commercial online games. *Foldit* is unique, however, in that it also utilizes simulation to engage players with content representative of real-world protein folding.

One useful way of thinking about the practice of *Foldit* is by analyzing the expert trajectories involved in playing. Expertise with a game is more than attaining knowledge of game mechanics; instead it is engaging in expert gaming practice (Chen, 2012). This mirrors Strand 5 from the six strands of science learning (National Research Council, 2009), in that it recognizes that doing science is not just learning scientific concepts and facts; it is also engaging in the practice of science. The six strands (p. 43) are:

- Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.
- Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.
- Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.
- Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.
- Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools.
- Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

We want to push this idea even further and ask whether engaging in the practice without knowing the facts can be considered science. In other words, we ask if all six strands are necessary for a learner to be considered doing science. To this end, we also considered the NRC's (2012) list of eight science & engineering practices in Dimension 1 of their framework for science classrooms (p. 42):

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Yet, upon examination of the data, it became apparent that much of the talk around playing *Foldit* is representative of a hybrid space between science and gaming practices where a diverse set of scientific identities and understandings of science coexist among the players. Furthermore, many players consider themselves as participating in the scientific endeavor even if they do not consider themselves knowledgeable about the scientific concepts. The fact that they are indeed contributing to major scientific findings forces us to reconsider what counts as science.

Data and Analysis

Our current analysis includes posts from online discussion forums. We coded for whether the content of players' communication represented science content, game play strategy development as evidence of scientific practice, or a combination of the three. Further coding highlighted the six strands of science learning with an additional seventh strand that emphasizes knowledge navigation over time (Stevens et al., 2008) and the eight science & engineering practices for classrooms (National Research Council, 2012). Below are examples of just two categories of talk found in the *Foldit* forums. A more thorough review will be covered in a future paper.

Intertwined Gaming and Science

Though scientific language may be taken up by the participants, its purpose is to develop new and efficient methods of game play to improve scores, recipes, and reputations. In the following exchange between two players we see evidence of scientific expertise integrated with building gameplay expertise. The first player said,

> Does the score completely ignore salt bridges, metal ion coordination, disulfide bonds, and hydrogen bonding along the side chain? These are pretty important interactions in proteins. (charlesabrams, April 23, 2008)

The second player responded with

> You are obviously more technically aware of this protein folding business then I, but I can tell you by observation that hydrogen bonds are indeed factored both in

> to the score, and into the behavior of the proteins, as well as shown on your display (If you chose them in the VIEW menu). Indeed, I believe you will find puzzle 44 very interesting. It begins with a few hydrogen bonds, and you will find you don't score over about 8,900 without making many more. (feet1st, April 24, 2008)

The talk from these two forum posts clearly mention scientific terms (e.g., hydrogen bonds), but it is within the context of the puzzle game. The second poster is observing that her/his score improves as the hydrogen bonds are manipulated in particular ways and that these elements do affect each other within the modeling of the protein. This poster's understanding of the science is closely entwined with her/his understanding of how the game works, and it could be that prior knowledge about how the structures of proteins *should* behave are not influencing her/his observations.

Contributions to Science

Some players recognize that, by playing *Foldit*, their efforts contribute to a scientific community, but the contribution is through the quality of their game play, not necessarily their knowledge of scientific content. In response to an original post on whether players have scientific knowledge, this player openly acknowledges it is unnecessary to know science but still wants her/his work to be used in research:

> Being totally novice, I think intuition plays a very big part here. I just learned the basic rules and am doing rather well, if I do say so myself. (Rather well being in the top 20 %, but maybe I was lucky, and struggling) So I would have to say…. that you don't need scientific knowledge to be good at this game…. Just go with what looks and feels good…. I do hope that even though I'm not top dog, my solutions will be used in the research..….If not, I might as well be playing Battefield [sic], or something. (coltzan, Oct 22, 2008)

Other posts show that some players have sophisticated gaming knowledge that helps them contribute to *Foldit*'s design. Another poster states,

> … your average gamers who are used to built-in tutorials that cover all the basics (every game I've ever played) are going to spend much time outside the game learning...let's be realistic if we are trying to reach gamers as the target audience for crowd sourcing... (taurine, July 31, 2009)

This post illustrates that standards and practices from the gaming community carry as much weight in the viability of successful game play as accurate representation of scientific content.

Significance and Implications

The initial findings of our analysis suggest that ~~learning~~ knowing scientific content and ~~learning~~ participating in scientific practice are segmented into different populations of players and that understanding one (in the context of *Foldit*) does not necessitate the understanding of the other. Becoming a good player requires an ability to develop good routines and processes, including possibly running other players' recipes. It also helps to have developed a *disciplined perception*

(Stevens & Hall, 1998) that allowed rapid recognition of particular protein configurations and patterns.

Additionally, the actual embodied activity of playing *Foldit* does in fact mirror one of the activities in a biochemistry lab. The physical, computer-mediated manipulation of a 3D model looks like what biochemists do at their computers. This is not surprising given that CGS designed the game after existing modeling applications for protein simulation. In essence, *Foldit* represents a very successful marriage between scientific modeling software and the puzzle-game genre with complementary social supports built-in. Would a different game enculturate players into scientific practice as successfully if it was not based on existing scientific tools?

Though learning the science of protein folding is not at the forefront of the design objectives of *Foldit*, through regimented but self-regulated practice, some players demonstrate a high proficiency in protein folding. Investigating high player proficiency in protein folding through expertise in 3D manipulation and mastering *Foldit* as a system shifts the educational focus from content domain expertise development (i.e. deep understanding of the intricacies of protein folding based on knowledge of protein laws) to participation in scientific practice. Through game play, players concurrently develop and demonstrate an understanding of scientific practice without domain expertise.

At the same time, *Foldit* could be an entryway for some players into the science of proteins as well as scientific practice. Without engagement with *Foldit* and its community, exposure to protein folding and scientific practice may not have occurred for some players. In other words, players who enter as gamers may learn the science behind protein folding and protein structures or the scientific significance of specific puzzles through their participation in *Foldit*.

As with any discipline that develops norms for what counts as expertise, the practice of playing *Foldit* became more narrowed over time. The techniques and tools used to play have become more sophisticated, and there is more agreement on general initial strategies to take while playing. Evidence of this group alignment work can be found in an early post:

> I thought it would be good to start a thread with some basic tips for people to use in playing the game. It is certainly much more enjoyable when you have a feel for what you are doing. I don't really scientifically know what I'm doing. But I've been studying Rosetta for a long time. And spiralling those native sturctures around trying to see patterns from one protein to the next. And I seem to be scoring well, so I thought I would share some about things that seem to be working for me. I hope others will do the same and post their ideas here. Some combination of all of them will ultimately be a better approach.
>
> In fact, **let's make it a standing rule that if you take the top score when a puzzle is closed, you have to post a tip to this thread.** (Rosettamod, January 29, 2008)

In addition, for the participants in the online forum community these norms extend to specific expectations for how to engage with the community and contribute to group play and for what counted as appropriate conduct in individual puzzle problem solving. In a long discussion thread on the introduction of group sharing of puzzle solutions, many players expressed concern about receiving undue credit (receiving a high score) for work that depended heavily on the contributions from a previous player. For example, one poster said

> I have to agree...I have the same problem. I was stuck at one point and looked at a file share of a person in my group and it jumped me up to their level. I was able to improve upon it, but I feel like they did most of the work to get me there (jumped from #26 to #4!!) Don't like the idea of that. I would much rather just be able to look at their model for comparison without suddenly acquiring credit for all their work. (sullivanml, May 31, 2008)

Later on, another poster highlighted this tension between game score and the purpose of sharing to help the overall scientific endeavor:

> While I think everyone agrees that the most fair way for scoring and ranking is to not allow sharing, but this is not the best solution for the science and discovery the game is based on. The sharing of ideas and discovery is integral to science. Someone might get stuck on an initial fold and give up, but they share that fold and someone uses that starting point to create a groundbreaking protein structure. Without sharing that scenario would never happen. Removing sharing will severely hinder the potential of the foldit experiment. We all have to remember that this is a science experiment first, fun game second. They will find a compromise somewhere along the lines. (Ghettogumby, June 3, 2008)

Eventually, the *Foldit* development team decided on awarding individual and group scores, as well as separate scoring for individual players who submit original solutions and players who modify an existing solution.

The forum community around the game shows us that science and gaming cannot be extracted from each other in the discourse of *Foldit* players. This allows us to see see just how complex and deeply situated *Foldit* play is. If we expand our view of the landscape of their practice, it begins to represent a microcosm for the larger community engaged in protein science. The *Foldit* players represent one tiny part of the larger whole.

We feel that the need for additional research and understanding about science learning in informal settings, such as in online communities represented by the *Foldit* player base, cannot be emphasized enough. These emergent learning environments not only help us consider how science can be understood through non-traditional informal gaming settings; they also help us reconsider our very definitions of doing science.

References

Bohannon, J. (2009). Gamers unravel the secret life of protein. *Wired* (4/20/09). Retrieved from http://www.wired.com/medtech/genetics/magazine/17-05/ff_protein?currentPage=all

Chen, M. (2012). *Leet noobs: The Life and Death of an Expert Player Group in* World of Warcraft. New York: Peter Lang Publishing.

Cooper, S., Khatib, F., Treuille, A., Barbero, J., Lee, J., Beenen, M., Leaver-Fay, A., Baker, D., Popović, Z., & *Foldit* players. (2010). Predicting protein structures with a multiplayer online game. *Nature, 466*, 756–760. doi:10.1038/nature09304

Gee, J.P. (1999). *An introduction to discourse analysis: Theory and method.* New York: Routledge.

Khatib, F., DiMaio, F., *Foldit Contenders Group, Foldit Void Crushers Group*, Cooper, S., Kazmierczyk, M., Gilski, M., Krzywda, S., Zabranska, H., Pichova, I., Thompson, J., Jaskoiski, M., & Baker, D. (2011). Crystal structure of monomeric retroviral protease solved by protein folding game players. *Nature Structural and Molecular Biology, 18,* 1175-1177.

Latour, B. (2005). *Reassembling the social: An introduction to actor-network theory.* Oxford and New York: Oxford University Press.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Committee on Conceptual Framework for the New K-12 Science Education Standards, Board on Science Education, National Research Council. Washington, DC: The National Academies Press.

National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits.* Committee on Learning Science in Informal Environments. P. Bell, B. Lewenstein, A.W. Shouse, & M.A. Feder (Eds.). Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Salen, K. (2008). Toward an ecology of gaming. In *The ecology of games: Connecting youth, games, and learning* (pp. 1–17). Cambridge, MA: The MIT Press.

Shrum, W., Chompalov, I., & Genuth, J. (2001). Trust, conflict and performance in scientific collaborations. *Social Studies of Science, 31*(5). 681-730.

Steinkuehler, C.A. (2006). The mangle of play. *Games and Culture, 1*(3), 199-213.

Steinkuehler, C.A., & Duncan, S. (2008). Scientific habits of mind in virtual worlds. *Journal of Science Education and Technology, 17*(6), 530-543. doi:10.1007/s10956-008-9120-8

Stevens, R., & Hall, R. (1998). Disciplined perception: Learning to see in technoscience. In M. Lampert & M. L. Blunk (Eds.), *Talking mathematics in school: Studies of teaching and learning* (pp. 107-149). Cambridge: Cambridge University Press.

Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education*, *97*(3), 355–368.

Taylor, T. L. (2009). The assemblage of play. *Games and Culture, 4*(4), 331-339.