Bio-Gaming: Videogames as Tool to Teach Cell Biology

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Abstract

This study describes the cognitive and social differences between students working with *Virulent!*, a videogame devoted to cell biology, and students working in a traditional class activity involving reading text and graphs. Specifically, this study analyzes the conversations and cognitive processes that arise when kids play and talk about *Virulent!*, a game that requires players to control the behavior of a virus and interact with cell structures in a way that resembles the actual behavior of biological agents. Results show that using the videogame creates more social interaction focused on content during the study time, and produces higher levels of understanding regarding the temporal relationships and the biological mechanisms involved in the viral replication process.

Learning Advantages of Videogames

This study explores the role of videogames in the learning of cell biology, particularly in the integration of information coming from a text that describes viral reproduction. Differences between learning in videogames and learning in traditional class activities can be explained by three factors: the representational, social and pedagogical advantages of videogames.

Moving Parts: The Representational Edge of Videogames

Different forms of content presentation imply different cognitive constraints. Larkin & Simon (1987), for example, point out that graphs are more efficient than text to present certain types of content because they make explicit information that is hidden in text-based representations. In the same way, videogames and simulations have representational advantages over graphs because they can present temporal relationships that are not visible in graphs. Additionally, videogames and simulations can present emergent processes in a way that makes clear how the micro and macro levels relate. This is important because research in cognitive psychology has shown that understanding emergent processes is difficult, creates misconceptions in several content domains and requires conceptual change and ontological reorganization to be achieved (Chi, 2005).

Playing Together: Social Interaction in Videogames

Social interaction around videogames is well-known. Videogames create communities of practice in which players develop skills and identities, share knowledge and conduct collaborative reasoning (Steinkuehler, 2008). This process of collaborative reasoning fosters scientific habits of mind, mathematical understanding and digital literacy (Black & Steinkuehler, 2009; Steinkuehler, & Duncan, 2008). Research shows that gaming communities use resources (e.g., online discussion boards) to build collective knowledge about the game, and to conduct modeling of game characteristics (Steinkuehler & Williams, 2009).

Teaching Each Other: Pedagogical Adequacy of Videogames

Videogames provide situated learning. In games, problem solving and learning are related to task goals in such a way that learners know the use and meaning of skills and contents within the context of the game (Gee, 2005). In the same way, learning activities within games are easily connectable to identities that are socially valued by the gaming community (Gee, 2008). Additionally, gamers engage in reciprocal teaching activities in which new members of the group are introduced to the practices, values and skills of the group. This process is facilitated by the fact that learning in videogames happens within the Zone of Proximal Development (Vygotsky, 1978).

Virulent! and the Understanding of Genetics

Virulent! presents the process of viral replication and the genetic mechanisms related to it. The understanding of genetics is challenging for many students. Students have problems to understand the origins of genetic disease, the nature of research in genetics and the characteristics of genetic explanation (Wood-Robinson, Lewis, & Leach, 2000). The challenge to understand genetics comes, in part, from the fact that genetics requires coordinating two ontologically different levels (Duncan & Reiser, 2007): The information and the physical level. Understanding the relationship between two different levels requires ontological reorganization and conceptual change (Chi, 2005). *Virulent!* presents the relationship between these levels by showing how both the cell and the virus genetic information are expressed using cell structures. In the process, students have the opportunity to observe the relationship between genetic material, proteins and organisms.

The game supports learning in two ways. First, it helps students to comprehend better the text by providing a representation to which participants can attach the incoming information. In this way the game facilitates the process of propositional integration. This process is fundamental for the construction of the mental models that support understanding and problem solving (Johnson-Laird, 1980). Second by showing how interactions at the micro level explain observable traits, the game helps students to understand the emergent nature of biological processes. Understanding the relationship between different levels of description has been considered core for the understanding of science in general, (Chi, 2005), and of genetics in particular (Duncan & Reiser, 2007). Research on genetics education has additionally shown that the comprehension of this relationship is challenging for students (Lewis & Kattman, 2004).

Game Design: Bringing Biological, Educational and Design Expertise Together

The game was designed by the Educational Research Challenge Area (ERCA) group at the Wisconsin Institute for Discovery-Morgridge Institute for Research (WID-MIR) with the collaboration of experts in the field of virology. For this reason, the game presents adequate disciplinary knowledge. More important, the game uses the educational advantages of videogames, such as interactivity, agency, collaborative reasoning and situated learning (Gee, 2005; Squire & Durga, 2009: Steinkuehler & Duncan, 2008), to illustrate the mechanisms that at the micro level explain viral reproduction and genetics. To achieve this goal, experts from the WID-MIR in the field of virology were brought together with experts in design, education, computer science and psychology during an iterative 16-months process. Initially content experts elaborated descriptions of the viral reproduction process (e.g., graphs) and explained them to the design group. These descriptions included a list of different types of viruses (e.g., positive-strand RNA viruses, DNA viruses), their specific paths during the viral reproduction process, and their use of cell structures. From that description, design experts produced paper prototypes of several possible games that represented the viral reproduction process using diverse game mechanics (e.g., role-playing game using dices / strategy game in a board). Then experts reviewed the prototypes to make them closer to disciplinary content. Several rounds of this process were conducted in the different stages of the design process (e.g., paper prototype/initial computer-based prototype). Also several play tests were conducted during the game design and development process. Using all the available information, the game was modified in order to present an adequate description of the viral reproduction process and to respond to user preferences regarding usability and game mechanics.

Method

In this study, participants were assigned randomly to two groups. In the control group (Traditional), students read a text on the polio virus, studied the graphs that explain the process, and solved collaboratively a questionnaire regarding the viral reproduction process. In the experimental group (*Virulent!*), students read the same text and played *Virulent!*. During the study period (about 1hr), students in both conditions were asked to think aloud (Ericsson & Simon, 1993) and to talk to each other in pairs. After a reasonable period of time, students were asked to explain the process of viral reproduction using a drawing and to think aloud.

Students' conversations were audio recorded and then coded in three levels: *Interaction*, *interaction focused on content*, and *multimodal interaction focused on content*. These categories were coded hierarchically, that is, a code was created for the deepest type of interaction presented in a segment of time. The reason for this decision was that *multimodal interaction* implies *interaction focused on content*, and *interaction focused on content implies interaction*. *Multimodal interaction* was coded when students talked about and referred to two different sources of information in different formats during the study period (e.g., computer screen, game instruction, graphs, or text). *Interaction focused on content* was coded when students talked about content knowledge, the activity and the documents. Finally, *interaction* was coded when students talked about a topic not related to the class activity.

As part of the evaluation, students were asked to draw a cell and explain the viral reproduction process, while thinking aloud. These explanations were coded according to the presence of expressions indicating temporal relationships and viral reproduction mechanisms. For temporal relationships, the coding criteria implied the presence of temporal organizers and the segmentation of the process in steps (e.g., the virus first has to find a receptor, then …). For viral reproduction mechanisms, the criteria required a description of an interaction that intervenes in the process of expression and copy of the virus genetic material (e.g., it has to make a copy of its RNA: it has to get energy from the mitochondria; it has to find a receptor similar to those in its membrane).

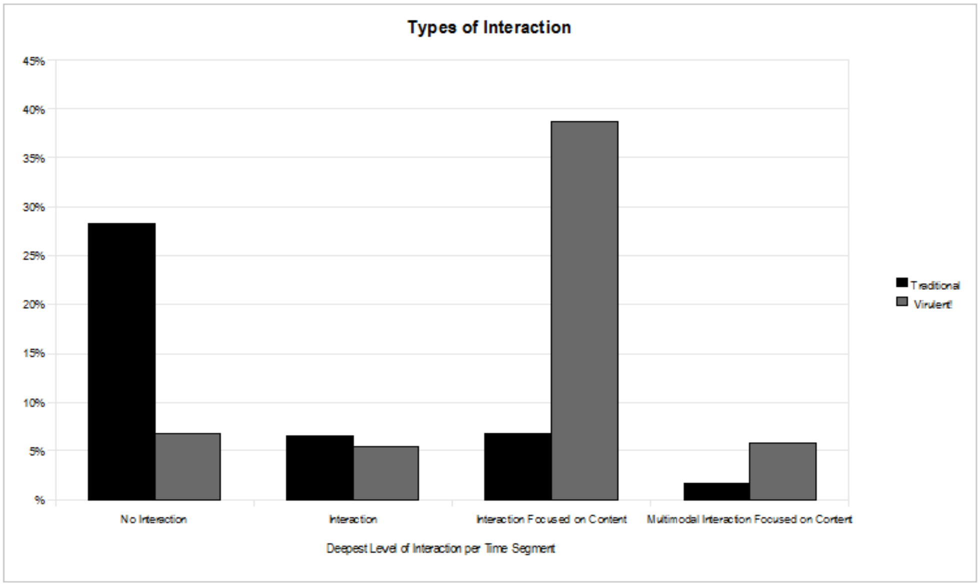

***Figure 1*. Levels of Interaction during Study Time.**

Results

Data suggest that the experimental condition produces higher levels of social interaction focused on content than the control condition (Figure 1). This difference is produced because *Virulent!* creates an environment where students informally talk about the game. The game is what Leinhardt and Crowley (2002) call an object of talk, a token around which disciplinary conversation arises in the context of family or peer interactions. In the traditional class activity, although students were encouraged to study the content together, they reviewed the content individually and had few questions about it. In the game condition, by contrast, questions on content and strategic decision making were more common. The experimental condition also produces higher levels of multimodal interaction focused on content. That is, students in the experimental condition went back and forth between text and game, while students in the control condition usually read the text first, and then looked shortly to the graphs, but they did not do it simultaneously. This difference might be a consequence of situated learning in games in which the text is presented in the context of the activity, and therefore linked to the goals of the task. By consequence, the text is used in relationship to all the other activity-related elements because they are linked to similar goals in the task structure (e.g., the game problem space).

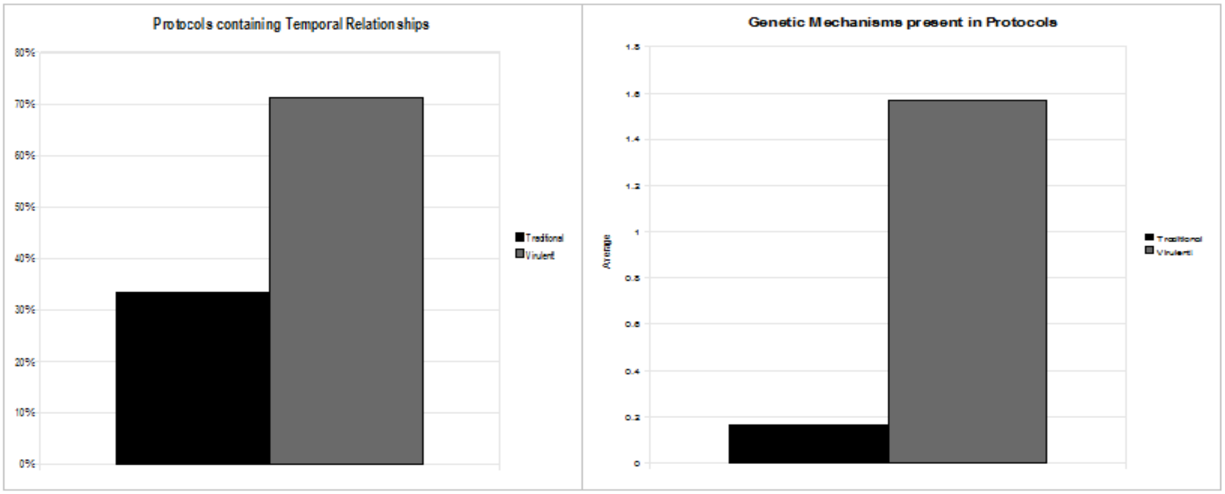

***Figure 2*. Temporal Relationships and Viral Reproduction Mechanisms in Protocols.**

Additionally, the game facilitates the understanding of temporal relationships that are hard to grasp for students in the control condition (Figure 2). This fact is evident in the protocols that show that students in the experimental condition are better than students in the control condition in establishing the order of events in the viral reproduction process. Table 1 shows two examples of typical answers from both groups. The student in the game condition has a dynamic representation of the viral reproduction process that includes different sub-goals and steps associated to them. In the traditional condition the student has a static representation of the process based on the parts of the cell, but without any mention of how virus and cell structures interact.

Virulent!	**Traditional**
"mmm… voy a dibujar el polio [virus](silencio y risas) acá voy a dibujar la célula… y… (risas)… el recep… si el receptor tiene que encontrar un…. Tiene que encontrar un receptor que sea igual [igual al de su membrana]...eee, después tiene que hacer una copia de su ARN… bueno por acá [señalando el ribosoma] saca su ARN… ee… Acá está el núcleo de la célula".	"Pues, yo me acuerdo que era el núcleo, la pared celular, los lisosomas, la vacuola, la pared celular, la pared nuclear, pero no me acuerdo de más".
"mmm. I´m going to draw the polio [virus] (silence and then laughs), here I´m going to draw the cell and (laugh) the receptor... it has to find a , it has to find a receptor equal [equal to the one in its membrane]... eee, and, after, it has to make a copy of its RNA... well here [pointing to ribosome] it gets its RNA... here is the nucleus of the cell..."	"Well, I remember that it was the nucleus, the cell wall, the lysosomes, the vacuoles, the cell wall, the nuclear wall, but I don´t remember anything else".

***Table 1*: Examples from protocols.**

A similar pattern was identified in the drawings of the viral reproduction process in which students in the game condition included arrows and numbers to describe the steps of the viral reproduction process (Figure 3). In a similar fashion, students in the game condition were better than students in the control condition in remembering the mechanisms participating in viral reproduction. When protocols of students´ drawings were coded, it was evident that students in the control condition remembered more of the interactions between virus and cell structures that participate in the viral reproduction process (e.g., find a receptor, make copies of RNA).

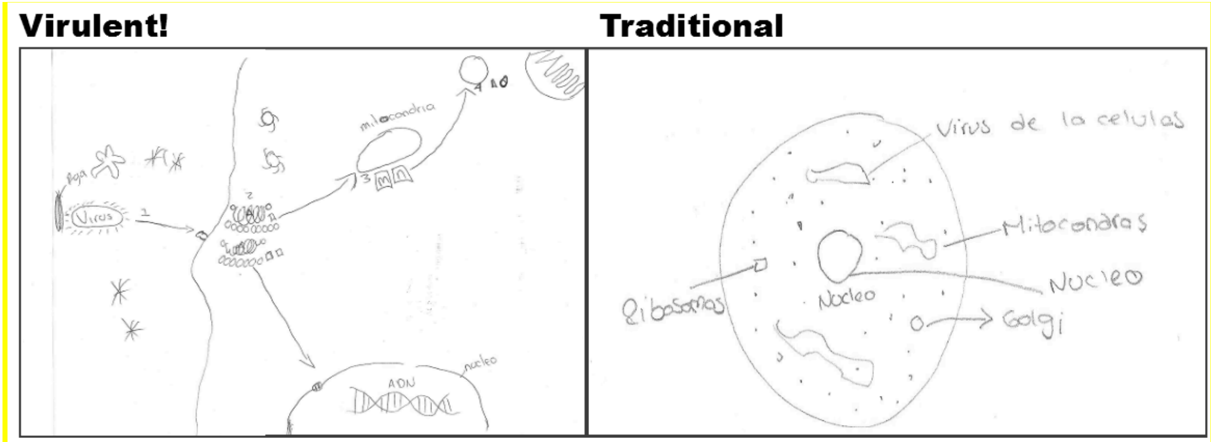

***Figure 3*. Examples of Drawings Made by the Two Groups.**

Conclusions and Further Developments

This study shows that videogames can be used to bring disciplinary content to school environments in a way that promotes interaction and helps students to better understand dynamic processes. In this sense, this study shows that videogames can be a powerful tool to transform schools in ways that are consistent with the cognitive and socio-cultural perspectives in the learning sciences. At a cognitive level, videogames provide students with a better representation of temporal relationships and emergent processes. At a socio-cultural level, videogames create an environment that fosters informal, non-directed, interaction focused on disciplinary content. The findings, however, need to be read with caution. The differences between the experimental and the control group are important, but small in absolute terms. This fact is especially evident when the differences in the number of viral reproduction mechanisms remembered by students are analyzed (Figure 2). The experimental group mentions 1.57 mechanisms, while the control group mentions less than .2 on average. The point is that the absolute number of mechanisms described in the text and necessary to succeed in the game is higher than 10. Students in the game condition remember more than students in the control group, but still their absolute scores were low. Part of this small effect comes from the fact that this study conducted a short intervention (1 hr approx.). It is necessary to conduct a proper design experiment with at least 8 hours of game play to allow students to finish all the game levels. A longer intervention will allow students to interact several times with the strategic actions involved in the game and to build a more robust cognitive representation of the game´s problem space. In the same sense, it is necessary to study how *Virulent!* fosters interaction in online environments, when deployed in out-of-school environments, for long periods of time (6 months). This type of study will provide information useful to evaluate whether *Virulent!* produces the same dynamics of collaborative reasoning observed in online environments related to *World of Warcraft* and other videogames (Black & Steinkuehler, 2009; Söbke & Corredor, 2011).

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