Can't See the Science for the Trees: Representations of Science in Videogames

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ABSTRACT
Depictions of scientific development in popular media carry significant influence over the way that the public envisions science as a process and as an institution. One such popular depiction of science is the "Tech Tree," a common game mechanic in strategy videogames. This mechanic is often problematic, as in its most common form, the tech tree depicts a technologically deterministic view of science.

General Terms
Algorithms, Human Factors, Theory.

Keywords
Tech Tree, *Civilization*, Science Communication, Technological Determinism

1. INTRODUCTION
Media representations of technological and scientific development, though not always accurate, play an important part in the public understanding of science. Depictions of science in mass media such as television and film help to create conceptual frameworks of attitudes and understanding in the public consciousness [25][18]. The significance of these frameworks is far reaching, impacting such issues as public acceptance of technology, public engagement in scientific policy, and public support of scientific research [4]. This significance seems to be widely understood in the context of some media, such as film, to the extent that even scientists themselves occasionally feel the need to step in to debunk perceived inaccuracies [18]. Other media, such as videogames, have thus far received considerably less scrutiny.

There are, however, a number of reasons that videogames warrant increased attention from scholars. In addition to their ever-increasing ubiquity in the media landscape, playing videogames has been noted as a catalyst for inspiring an early interest in technology and computer culture [4] [3] [12] [29] (see also [8]). As these videogame players enter computer science and other technology-related fields, they bring with them the attitudes and conceptual frameworks of science that were in part shaped by the games they play. Thus, the depiction of science in videogames is far from insignificant.

One of the games most oft-studied by academics is *Sid Meier's Civilization* [23] and its associated franchise. In the series, which now numbers five games as well as numerous spin-offs and expansions, the player takes control of a nation and must guide her people from the stone age to the near future. Since the scope of the game touches on all of recorded human history, it has attracted the interest not only of videogame scholars, but of historians, archaeologists, and many others within academia. Such studies often focus on the educational potential of *Civilization* as a tool in the classroom (see [2] [21] [32] [13]). Although discussions of the game's educational value often elicit jokes about students learning how the ancient Egyptians conquered the Mongol Empire with jet fighters [5], the virtue of *Civilization* games as a learning tool lies not in their ability to assist rote memorization, but in their ability to model historical developments procedurally [2]. Indeed, counterfactual historical thinking like that fostered in *Civilization* is often a desired goal in designing educational games [36][13]. It is perhaps not surprising, then, that *Civilization* often comes to the forefront in discussions about videogames and learning.

One of the most salient features in the representation of history created by the *Civilization* franchise is the "Tech Tree," the representation of the technological and scientific progress of the player's civilization over the course of the game. As a game mechanic, the Tech Tree is so influential as to have become an integral part of strategy games like *Civilization*, as well as many other games from different genres. Indeed, as Pobłocki notes, while *Civilization* and other strategy games often offer multiple victory conditions (conquer the world, reach some scientific achievement, dominate international politics, etc.), the path to achieving these goals is always the same: Climb the tech tree faster than your opponents [28].

The tech tree manages to reduce and unify the history of every scientific discipline into a single visually satisfying graph. It embodies a specific understanding of science, not only by curating a list of the most important milestones within the newly integrated realm of science, but by defining the relationships between these events. As scholars like Voorhees have pointed out, these

Proceedings of the 10th International Conference on the Foundations of Digital Games (FDG 2015), June 22-25, 2015, Pacific Grove, CA, USA.
ISBN 978-0-9913982-4-9.

relationships between cause and effect are so strongly defined that many players have reduced the act of play itself to a streamlined algorithm or formula, with the experienced player building and researching certain items on specific turns in order to optimize her returns [38].

Due to the centrality of the tech tree to the mechanics of *Civilization* and other games, it has been repeatedly examined by scholars on account of its historical imprecision [39], its ideology of Western imperialism [28] [6], and its inaccurate depiction of science [38] [11]. Although each of these criticisms could easily warrant further study, this paper is primarily concerned with the third of these themes, the way in which the tech tree depicts scientific and technological development. Specifically, I argue that the tech tree in its most common implementations depicts a technologically deterministic view of science that conflates scientific and technological development. Although this paper is not a study of historical inaccuracy or Western bias in games *per se*, the view of science I critique converges with such themes in many instances.

Also of relevance to this study is the meaning of the term "tech tree." As previously mentioned, the tech tree mechanic went on to be used and appropriated by many different games across a number of genres. As the mechanic spread to new kinds of games, the term began to be used more and more loosely. In addition to hierarchies of technoscientific knowledge that the player could develop, such as in the *Civilization* series, the term "tech tree" has also been applied to organizations of building prerequisites, such as in *Shogun: Total War* [35] and *Heroes of Might and Magic II* [26], and to even more abstract systems, such as the sequence in which materials must be progressively gathered in order to create increasingly complex objects in *Minecraft* [24]. In essence, nearly any kind of hierarchical system of abilities within a videogame can be colloquially referred to as a "tech tree," making it expedient for us to develop more precise definition in order to select meaningful objects of analysis.

In the context of this paper, I use the term "tech tree" to refer to any system of unlockable abilities that are representative of technoscientific advances. Since such systems are usually complex and nuanced, they are most common in (though not exclusive to) turn-based strategy games. Although sometimes present in real-time strategy games, such games more often feature a hybrid system that combines building hierarchies (such as those in *Heroes of Might and Magic II*) and *Civilization*-style tech trees. Additionally, real-time strategy games often tend to represent individual military engagements, which have a limited scope both in time and space (a game of Starcraft might be said to represent a number of days, whereas a game of *Civilization* generally represents around 6000 years). As such, the "researching" of new technology within the game is more representative of requisitioning better equipment from headquarters or of getting an existing technology working in the field than of making a series of scientific breakthroughs in the middle of a battle. Therefore, most of the examples of tech trees examined in this paper will be taken from turn-based strategy games.

2. SCIENCE AND TECHNOLOGY

The relationship between science and technology has at various times throughout recent history been the subject of fierce debate. The classification of technology as artifacts and science as knowledge [17], or the idea of "technology as applied science" [19] continues to be commonplace. While the ubiquity of such models lends them an air of authority, they have little basis in the historical relationship between science and technology. Indeed, Kline points out that the model of technology as applied science is not only a product of the twentieth century, but a deliberate rhetorical strategy on the part of interested groups [19].

Although one could argue based on such examples that the precise definitions of "science" and "technology" are far from stable and have in fact changed over the course of history, it would be misleading to say that science and technology (whether going by these names or not) have ever been the same thing. As Volti notes, "most technologies have been developed and applied with little scientific input" [37]. Indeed, in many periods of history, science and technology have had an almost inverse relationship. Volti gives the example of ancient Greek science, which was incredibly advanced for its time, yet had very little influence on their technological developments, which were far less significant. The Romans, on the other hand, made substantially fewer scientific breakthroughs, yet achieved remarkable advances in technology and engineering. Similar significant technological advances occurred throughout the middle ages, despite the conspicuous lack of scientific learning during the same time period, while the sixteenth and seventeenth centuries, the situation was once again reversed [37]. These examples are not meant to demonstrate that science and technology are in any way mutually exclusive (there are certainly plenty of counterexamples of the two coexisting peacefully), however, it does illustrate some of the significant problems with many popular models of science and technology.

If technology and science are neither the same thing, nor two opposing forces, how are they related? While a detailed analysis of this complex relationship is beyond the scope of this paper, it suffices to say that while the two concepts are independent, they do influence one another in certain situations. One example is in the development of scientific instruments, such as telescopes, computers, and bubble chambers. While these instruments themselves are technological artifacts, relying on people with technological expertise to build them, they are necessary for achieving the level of precision with measurements necessary to make scientific claims [37] [20]. By the same token, technologists have no need to increase the accuracy and precision of these instruments unless this increased precision will contribute to the creation of scientific knowledge [20].

This interrelation between instruments, ideas, and objects of study can also be viewed as what Hans-Jörg Rheinberger refers to as "experimental systems." He notes that while experimentation ideally transforms the object of study or into a stable technical object, these in turn create new objects of study, shaping the experimental system and guiding it down unexpected labyrinthine pathways. With the final structure of an experimental system unknown at its inception, the product of the system cannot be generally be anticipated. Despite the contingent nature of the experimental process, it is still difficult "to avoid the illusion that it is the inevitable product of a logical inquiry" [30]. Thus, it becomes easy to conceptualize all technoscientific endeavors as a

simple and direct progression linking concept to concept, question to answer, science to technology.

3. TECHNOSCIENCE IN VIRTUAL WORLDS

Although scholars have been critical of such perspectives since the mid twentieth century, videogame culture is still steeped in technological determinism. Due to its prevalence in both Western consumer culture and in technology-oriented fields [31] [40] [14], this is perhaps not very surprising. Most videogames that make use of the tech tree tend to reproduce this deterministic view with varying degrees of complexity.

The the topology of a tech tree can generally be described as a directed acyclic graph [15], as progress generally moves in one direction, with certain nodes being prerequisites for unlocking others and eventually reaching some form of end point. The most basic form of this tree is a completely linear model, in which each node (other than start and end nodes) has exactly one prerequisite and is prerequisite for exactly one other node. Games that implement the tech tree in this manner, such as the Apple II game *Cosmic Balance II* [34], generally portray science and technology in very abstract terms. In the case of *Cosmic Balance II*, this is represented by advancing from "Tech Level 1" to "Tech Level 2" and so forth. These linear advances give the player a generic advantage over other players. In games that make use of tech trees as a more tangential mechanic, the tree and its nodes may have a more specific context, such as "Armor Level 1." Even when these advances are given more thematic titles, such as "Scale Armor" and "Plate Armor," the mechanical function of these advances is fairly self-explanatory: "Level 2" is better than "Level 1." When you achieve "Level 3," it will be better still. Science, in such models, is a very predictable, cumulative process.

The standard "branching tree" structure from which the tech tree gets its name is both more complex and more common than the simple linear structure. In a branching tree, each node (once again, with the exception of start nodes) has a single prerequisite, but may in turn be the prerequisite for multiple other nodes. Thus, advancing along the tech tree not only grants incremental advantages, but opens up new paths of research to the player. With these multiple paths of research, the mechanical benefits provided by technologies tend to be more nuanced than the simple numerical comparisons possible in the linear model, as well as generally having a far greater number of available technologies. While the in-game advantages provided by individual technologies may be more varied, the progress up the tech tree often remains incremental within individual branches.

More complex games such as *Civilization* feature an intertwined, mesh-like tech tree, with nodes potentially having multiple prerequisites as well being prerequisites for multiple other nodes. Compared to the examples above, these tech trees have a much more sophisticated model of technology, acknowledging to some extent the influences that different scientific disciplines have on each other. Despite their added complexity, these tech trees still embody many of the aspects of technological determinism found in simpler versions. Players "research technology" in order to achieve predetermined benefits that exist *a priori* within the game world. The research process simply consists of devoting the necessary amount of time and resources to arrive at a given technological milestone along the path of progress. Indeed, even the concept of "progress" as the march of invention toward some unknown utopia [31] is often reified not as some unknown ideal, but as an actual technology like any other. In *Civilization V*, the latest game in the *Civilization* series, this final technology is simply called "Future Technology," and exists at the convergence of all the other technological paths in the game [9]. *Civilization* and many other strategy games also allow players to achieve a "technological victory," which generally consists of some grand industrial project or simply researching yet another technology. Thus, science not only strengthens military and political power, it has the power to overcome them on its own - the ultimate example of technology as an end in itself.

4. CONFLATING SCIENCE AND TECHNOLOGY

The most common method by which players advance through a tech tree is by accumulating "research points" or "science." This process varies somewhat between games, though players most often acquire these points by having units gather them, much as they would any other resource, or by expending resources in order to "build" them. For example, according to the Civilopedia (the in-game reference) of *Civilization V*:

"You acquire technology by accumulating "beakers," which represent the amount of science your civilization possesses. Every turn your civilization gets a number of beakers added to its science pool. Each technology costs a certain number of beakers to learn; when you've accumulated enough beakers, you acquire the technology. When you get the new tech, your beaker pool is depleted and you start accumulating all over again, saving up for the next tech [9]."

The "beakers" of the *Civilization* series represent individual quantifiable units of scientific progress. The amount of beakers created can be increased by creating scientists and "great scientists," both of which are often depicted visually as caricatures of Albert Einstein. Thus, in the language of *Civilization* and other strategy games, science is the process of creating the standard building blocks that are used to achieve technological advancements.

There are many ways in which this model of science and technology fails to represent the actual process of scientific work, however, it is perhaps more interesting to note the number of ways in which the standard tech tree model recreates traditional cultural misrepresentations of science. Some, like the "heroic inventor" model of technological development [22] [37], embodied in the game world by the "great scientist," are included in the game in a very overt manner. Though implemented somewhat more subtly, technology is, once again, represented as "applied science" – the tangible mechanical advantage that the player gains from creating large quantities of abstract units of science.

It is also significant that throughout all the symbolism of beakers, scientists, laboratories, and points, there is an almost universal conflation of science and technology. It is not merely that science is depicted as being in the service of technology, but that science and technology are generally depicted as being part of the same enterprise. There are political consequences for both the blurring and sharpening of boundaries between science and technology –

both of which have been deliberately done by scientists and engineers at various points in time [19].

It is worth noting that this model also tends to pull other aspects of human culture under the umbrella of science. While some games like *Civilization V* have a "culture" mechanic that runs parallel to the tech tree, many games, including older games in the *Civilization* series, pigeonhole philosophy, religion, and the humanities into the tech tree as individual advances subordinate to the field of science and just as intimately and problematically linked with technological development.

5. THE TECH TREE AS A METRIC FOR CIVILIZATION

Deterministic views of technology can be problematic, particularly when held by individuals involved in technological development or in tech policy making. Even outside of such positions of power, however, notions that modern Western technological achievements were natural and inevitable can distort cultural understandings of non-Western cultures. Indeed, as Adas notes in his book, *Machines as the Measure of Men*, material culture, especially that related to science and technology, has long been used by Europeans as a measure of development of non-Western cultures [1]. If technological progress is assumed to begin at a common ancient start and flow inexorably toward some hypothetical future point, it becomes possible to rank cultures based upon their relative position within this continuum.

This ranking of other cultures as inferior in terms of science and technology had a great impact on the attitudes of Europeans toward non-Western peoples, as well as the ideology of Western imperialism [1]. As Adas notes, even cultures such as China, which was praised in the writings of Jesuit priests who had traveled there, as well as by writers such as Voltaire, were later criticized and mocked for their shortcomings in scientific and technological fields. As more Europeans traveled to China, this perceived technological backwardness became the justification for remaking the country along Western ideals [1]. Such ideologies of Western domination were even more apparent in other countries that lagged behind China in technological achievement.

The tech tree takes this general scale of cultural advancement and quantifies it into a rubric of discrete technological steps. There is no need for the likes of Voltaire to debate the merits of one culture over another, because such discrepancies are already noted and tallied within the game. Once the player of *Civilization* encounters another nation, it is usually a fairly simple task to discover if the new culture is two technologies ahead or five technologies behind. In fact, throughout the game, "historians" occasionally appear to write their seminal works. Although the framing fiction of these events implies an actual person writing a lengthy book, the actual mechanic merely shows the player a list of the rankings of different nations within the game, sorted by number of technologies, total population, or some other metric.

6. IMPLICATIONS FOR SCIENCE COMMUNICATION

For some time, scholars from many disciplines have looked at both the positive and negative influences of specific television shows, such as The X-Files [16][7], CSI [33][27], and Bill Nye the Science Guy [10], on public perceptions of science. The most salient issue for scholars in each of these examples is the accuracy with which scientific practice is portrayed. Television shows that are accurate in their representation of scientific knowledge, methods, and so forth are generally praised for bringing greater awareness to lay audiences or for encouraging positive perceptions of scientists as credible experts. Conversely, shows that make concessions in scientific accuracy for the sake of simplicity, genre conventions, or entertainment value are criticized for eroding the credibility of scientists, conflating science with high-tech magic, or otherwise undermining public perceptions of science. Perhaps the most well-known example of this is the alleged CSI effect, in which jurors who watch crime dramas have unrealistic expectations of forensic evidence or unwarranted confidence in unproven or even fictional forensic procedures [33]. Indeed, the concern for scientific accuracy in television and film is so common that it has transcended academia, spilling over into the public sphere through shows like *Mythbusters*, which often attempt to debunk such portrayals.

Unfortunately, neither the popular nor the scientific interest in these portrayals seems to extend to videogames. Granted, enlarging a frame of security camera footage to identify a reflection in a pair of glasses is perhaps more overtly problematic than tech trees that subtly embody ideologies of technological determinism and Western imperialism. At the same time, the fact that such mechanics often go uncritiqued by players is precisely why they warrant increased attention from scholars. Given the aforementioned connection between videogames and future interest in technical fields, portrayals of science in videogames should be considered important ways of understanding and shaping the fundamental assumptions about science that pervade computer culture.

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