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Using Science Fiction to Teach Science Facts

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Abstract

Hugo Gernsback, the publisher of one of the first science fiction magazines and the man whom some people label as the godfather of modern science fiction, defined science fiction as "a charming romance intermingled with scientific fact and prophetic vision" (cited in Westfahl, 1998, pp. 38-39). If science fiction truly includes scientific facts, it can have serious implications for the teaching of science to students, as well as implications for the general reader. Studies by Negrete and Lartigue, as well as by Stanhope, Cohen, and Conway, have provided evidence that information learned through narratives can be retained for a longer period of time than information learned through textbooks. The inclusion of science fiction novels into all levels of coursework, from high school to college, could promote learning of not only science but such skills as critical analysis, critical reading, research, and technical writing, to name a few. This paper examines novels by Michael Crichton, one of the most popular science fiction novelists of the 20th and early 21st centuries, to determine if contemporary science fiction writers include meaningful factual information in their novels.

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Chapter One: Introduction

Science fiction has long been a popular literary genre. From Mary Shelley's *Frankenstein* to H.G. Wells's *The Time Machine* to Douglas Adams's *The Hitchhiker's Guide to the Galaxy*, science fiction has fascinated readers of all ages around the world for over a century. Some read it for escapist purposes, while others have been so influenced by it that they become world-renowned scientists (Pohl). While there have been many popular science fiction writers, one of the most popular science fiction novelists of the 20th and early 21st centuries was Michael Crichton. His novels had a profound effect on the time period. First they were popular bestselling books, and then they became blockbuster movies.

This paper seeks to discover the truth, literally, behind science fiction. If science fiction novels contain truthful scientific information, perhaps they can be used to convey the latest scientific discoveries and information to the general public and to students. As discussed later, just science fiction in general, whether truthful or not, can have a profound impact on readers and lead them to scientific careers and greatness.

Research Questions

Readers learn about places, people, groups, jobs, laws, and many other subjects from fiction, and the information can stay with readers for long periods afterwards (Stanhope, Cohen & Conway, 1993). If that is true of non-fiction books and fictional novels alike, then it should also hold true for science fiction. Scientific facts can be conveyed through science fiction even for the most non-scientific of readers, as Negrete & Lartigue discovered through their study; "in particular, [the results of the study]

suggest that narrative information is retained for lengthier periods than factual information and that narratives constitute an important means for science communication to transmit information in an accurate, memorable and enjoyable way" (Negrete & Lartigue, 2010, p. 104). This literature analysis will focus on determining whether science fiction novels are meaningful ways of communicating scientific information. Therefore the research questions are:

- How much legitimate science is included in science fiction?
- How is narrative information retained?
- How can science fiction novels be used to teach legitimate science in today's high school and college classrooms?

Research primarily consisted of selecting literature on the main topics outlined in the research questions. In addition *The Science of Michael Crichton: An Unauthorized Exploration into the Real Science Behind the Fictional Worlds of Michael Crichton* was also referred to in order to determine how much science Michael Crichton actually inserted into his most popular novels (*The Andromeda Strain, Congo, Jurassic Park,* and *Prey*).

Chapter Two: Science Fiction as Science Fact

Is there actual, factual, legitimate science in science fiction novels? Hugo Gernsback, the publisher of one of the first science fiction magazines, defined science fiction as "a charming romance intermingled with scientific fact and prophetic vision" (cited in Westfahl, 1998, pp. 38-39). To Gernsback, scientific fact meant that the science fiction work "is, or intends to be, compatible with current scientific knowledge, and it communicates this knowledge to its readers" (McLeod, 2010, p. 171). Most importantly, the science fiction author makes the book "compatible with current scientific knowledge" (McLeod, 2010, p. 171) and that science fiction is factually based, even if the facts change over time. Even if the knowledge is later disproven, the book would still be considered science fiction because "the writers were at the time sticking to what was thought possible" (McLeod, 2010, p. 172). The science fiction authors "tried to reconcile their imaginations with current scientific doctrine. Of course, 'current' sometimes means what's in that morning's *New York Times*" (Pohl, 1994, p. 60). But the authors "get credit for their intention," and the books are not considered irrelevant just because they focus on obsolete science (McLeod, 2010, p. 172). "The foremost reality that science fiction deals with is change," so that is why readers accept that older science fiction novels contain obsolete scientific information (Pohl, 1994, p. 61).

The main reason Gernsback included "scientific fact" in his definition of science fiction can be traced to its fans; "what makes written sf [science fiction] distinctive as a genre is its relationship to its subject matter and to its core readership" (McLeod, 2010, p. 173). Science fiction fans are more critical and interactive than fans of any other

literature type; "the interaction (and overlap) between readers and writers includes criticism, and sf fans are quick to pick up on science errors or implausibilities" (McLeod, 2010, p. 173). Science fiction readers have an immense knowledge base, and they interact with each other at conventions, on the Internet, and through many different mediums. Because of this, science fiction authors have to be held to a different standard than authors of other forms of fiction. If a part of the science fiction novel is not plausible or if a theory has already been disproven, there will be uproar in the science fiction community, and readers will criticize authors for not following the "rules" of science fiction.

But that is not to say that science fiction always gets it right. McLeod points out that "current and recent sf has, of course, plenty of questionable science, which stays just within the limits of what science has not definitively ruled out…" (2010, p. 173). He even goes on to point out that not everyone follows Gernsback's definition of science fiction; "even the best modern sf can commit science errors, or admit to very speculative science" (McLeod, 2010, p. 173). But perhaps these errors are not without thought; "since science fiction does tend to incorporate phenomena no one has ever experienced, writers need to take some liberties, however devoted they may be to scientific accuracy" (Pohl, 1994, p. 59-60). But even with the errors committed and the speculative science included in written science fiction, "the fact remains that the science it does communicate is orders of magnitude more accurate than what we see in sf in other media…films, TV series, and computer games" (McLeod, 2010, p. 173).

Science fiction novels were loaded with real scientific theories even before Gernsback entered the scene. Mary Shelley's *Frankenstein,* published in 1818, "offers an

exceptionally fascinating insight into scientific issues of the day" (Fara, 2010, p. 19). Shelley was not only a writer but a researcher as well; "Shelley used fiction to present recent scientific discoveries … she drew on the latest research on electricity … she read many books and articles to make sure that she kept up to date on a variety of topics, including chemistry, evolution and Arctic exploration" (Fara, 2010, p. 19). Even before science fiction became a popular literary genre, Mary Shelley was making sure that the science in *Frankenstein* was real, authentic, and understood by the reader. This might be why *Frankenstein* ranks "as one of the earliest examples of science fiction" (van der Laan, 2010, p. 298). Aldiss labels *Frankenstein* as "the first real novel of science fiction" (2007, p. 353), and Shattuck says "all written and filmed works in the immense category of science fiction have their roots in the ground prepared by *Faust* and *Frankenstein*" (1996, p. 100). It could be supposed that Gernsback looked back to the earliest science fiction novels, *Frankenstein* included, in order to refine his definition of science fiction. Reading all of the scientific facts that Shelley put into her novel, Gernsback may have decided that including true scientific information of the day was essential to a good, successful science fiction novel.

We know that science fiction novels before Gernsback's time, and long after, have included scientific facts as a main part of the story. As McLeod theorizes, the inclusion of scientific fact can be traced to the devotion of science fiction fans and their interaction with writers, other fans, and non-science fiction readers alike. This interaction influences science fiction, and the fans demand factual scientific information in all science fiction novels. The practice of science fiction novels being scientifically plausible continues because of the fans and because of the tradition.

Michael Crichton

From Mary Shelley to Douglas Adams, science fiction writers have done the research, studied the scientific discoveries of their time period and included scientific information in their science fiction novels. One of the most popular recent science fiction writers is Michael Crichton, and he followed this tradition.

Michael Crichton was not new to science when he began writing science fiction. A graduate of Harvard and Harvard Medical School, he gained biotechnical expertise as a medical researcher before turning to writing. Perhaps this is why he wrote such riveting science fiction novels – because he understood the science behind them and could write about science for the masses. As the *Boston Herald* said, "few writers can make science as entertaining as does Crichton" (Crichton, 1987, back cover). But do those riveting science fiction thrillers actually teach readers about science and emerging technologies? Is the science in the novels actually factual? The *St. Louis Post-Dispatch* thought so; "Crichton is a master at blending edge-of-the-chair adventure and a scientific seminar, educating his readers as he entertains them" (Crichton, 1987, back cover). Kevin Grazier's *The Science of Michael Crichton: An Unauthorized Exploration Into the Real Science Behind the Fictional Worlds of Michael Crichton* examines Crichton's most popular novels to determine whether they contain scientific fact or falsehoods. The editor states; "It never ceases to amaze me how much research is put into [Crichton's] novels and, although ostensibly science fiction, how much real science the novels contain" (Grazier, 2008, p. x). There is no doubt that real scientific facts and theories are included in Crichton's novels. The hard part is sorting fact from fiction.

Science fiction depends on one point; "in a work of science fiction, the reader must grant the premise that whatever is stated as the case is literal and true" (Hartwell, 1989, p. xvii-xviii). And Crichton's readers are able to easily gain that premise because his novels "mix real science with creative, but plausible fiction … much of the equipment and methods described in the book [*The Andromeda Strain*] reflect the best technology available" (Pistoi, 1998, p. 2). Crichton mixes in fictional details in order to enliven his story, but the fact remains that his novels do contain references to real science, real technology, and real theories.

I will examine four of Crichton's most popular novels to determine the quality and factuality of the scientific information included. These novels are: *The Andromeda Strain* (1969), *Congo* (1980), *Jurassic Park* (1990) and *Prey* (2002). An analysis of the essays published in Grazier's book will point out the factual, and sometimes false, scientific information in Crichton's science fiction novels.

The Andromeda Strain

Michael Crichton's *The Andromeda Strain* was published in 1969 while he was still a graduate student at Harvard Medical School. The novel is about a deadly extraterrestrial organism spreading across the country after a military satellite, sent to look for new forms of life in space, crashes in the desert. The plot follows scientists as they try to isolate the organism, find out how and why it is killing people, and discover how to stop it.

The interesting thing about the Andromeda strain is that it is unlike any other organism found on Earth. It has the structure of a crystal, "something that we associate with inorganic objects such as minerals, not with a living organism" (Pistoi, 2008, p. 2).

The organism does not have DNA, proteins, or any other genetic material "that [is] typical of terrestrial organisms" (Pistoi, 2008, p. 2). So does that mean that Crichton is spewing scientific falsehoods in *The Andromeda Strain*? Absolutely not. There is the possibility that such organisms exist; "although there is no evidence of them on this planet or elsewhere in space, the existence of crystalline organisms is not just a science fiction's expedient, but a possibility that some researchers have seriously considered" (Pistoi, 2008. p. 5). Crichton may have read about the research into crystalline organisms before writing *The Andromeda Strain*. The existence of them has not been proven, but it also has not been disproven, so the novel "is, or intends to be, compatible with current scientific knowledge, and it communicates this knowledge to its readers" (McLeod, 2010, p. 171). While *The Andromeda Strain* does include speculation, it "stays just within the limits of what science has not definitively ruled out" (McLeod, 2010, p. 173). So, as Pistoi says, the Andromeda strain idea, while not proven and "although bizarre … is neither more nor less plausible than others" (2008, p. 5-6).

Crichton's *The Andromeda Strain* eerily spoke to real life events. Just as scientists in the novel did not believe there could be an organism made entirely of crystals, real life scientists had trouble believing that a protein was the cause of a new disease outbreak in the 1980s. It was the outbreak of bovine spongiform encephalopathy (BSE), more commonly known as mad cow disease, that baffled scientists and disproved all their theories about only bacteria and viruses being able to cause diseases. The discovery of mad cow disease spread panic throughout the world of biology because "BSE was not caused by the usual suspects, viruses or bacteria, but, instead, by something new and weird—an infectious pathogen that was so far from our idea of life

that it almost looked like a space creature" (Pistoi, 2008, p. 9). In the end, it was discovered that mad cow disease was caused by a protein. Just like the Andromeda strain, proteins do not have any genetic material. Crichton's "fiction" was not looking very fictional after the discovery of mad cow disease. In the end, it took a scientist "more than a decade before he could convince his colleagues about the existence of prions [proteinaceous infectious particles] … it turned out that the infectious prions were mutant forms of innocuous proteins called PrP" (Pistoi, 2008, p. 9-10) and that these prions were causing mad cow disease, not a virus or bacteria. Nobody believed the scientists because his theory went against all previously-held beliefs. But just because something had not been encountered before, prions or crystalline organisms alike, it does not mean that it is not possible. This was not the first instance of *The Andromeda Strain* eerily relating to real-life events that happened after its publishing.

In writing his first novel, Crichton adhered to one of the major underlying, often subliminal, messages of science fiction. He factored in "all the public and private concerns about what is happening right now, not in the future" (de Solla Price, 1976, p. 41). *The Andromeda Strain* was a fictional novel that addressed the public's fears of the Apollo 11 mission that was occurring; "When conceiving Wildfire, the fictional quarantine plant where Andromeda was being analyzed, Crichton was clearly inspired by NASA's Lunar Receiving Laboratory, and it is probably not a coincidence that *The Andromeda Strain* was released on May 12, 1969, only a few months before the launch of the Apollo 11 mission" (Pistoi, 2008, p. 12). And the disaster that overtakes Crichton's novel almost became reality a few months later.

> One day during December 1969, while examining Apollo 12 lunar rocks, technicians discovered a cut in one of the LRL [Lunar Receiving Laboratory] glove chambers, which could have exposed workers to contact with contaminated air. Exposed personnel were sent to quarantine, but, according to the report, some escaped the facility before they could be forced into isolation. We can only imagine what would have happened if these people were contaminated by a dangerous and unknown extraterrestrial pathogen (Pistoi, 2008, p. 11-12).

So while it is labeled as science "fiction," Crichton's novel has definite scientific fact in it, and the storyline almost played out in reality. But that doesn't mean that Crichton only writes truthful statements; he does make some mistakes. While his Wildfire facility is based on a real facility, he does get some information incorrect.

> To reach the bottom level, which had the highest security level, scientists had to undergo a series of decontaminating steps, including radiation treatments and drugs that eliminated microorganisms in the skin and the intestine. Incidentally, many of these treatments would be possible in reality only at the cost of killing people (Pistoi, 2008, p. 12).

Crichton also includes some very hard-to-believe science in his novel, at least for Pistoi; "Honestly, it's difficult to imagine how a creature that has survived in the harshest conditions of outer space could be so sensitive to acidity: let's say it sounds as plausible as the Terminator being afraid of a snowball" (Pistoi, 2008, p. 15). But while Pistoi finds Andromeda's downfall to be unbelievable, it isn't uncommon, especially in the medical world Crichton was immersed in during his writing of the novel; "Crichton has probably taken [this acidity idea] from his medical background: as a doctor, he knew that the pH is a very critical issue for the survival of most germs. Microorganisms on Earth can only thrive within a narrow range of acidity; therefore, our body uses pH as a first line of defense against infections" (Pistoi, 2008, p. 16). So while is hard to believe that a deadly organism can be killed by something as drab as the acidity of a person's pH, it actually happens in the real world.

Crichton's first novel, which was his first bestseller and made him a rising literary star, may not be entirely based on science fact. But ultimately, Crichton made more correct scientific statements than mistakes in *The Andromeda Strain*, and readers would have learned a great deal about science and the Apollo 11 mission by reading the novel.

Congo

In *Congo*, Michael Crichton takes a different approach to science fiction. The main threat to the novel's characters does not come from something as scientific as a crystalline organism, nanoparticles, or climate change. The scientific threat in *Congo* is from intelligent, murderous gorillas.

Published in 1980, Crichton includes a lot of real ape language research in *Congo*; "In writing *Congo*, Michael Crichton did his homework well and researched the history of ape language studies" (Maestripieri, 2008, p. 60). The plot focuses on an ape, Amy, who knows human sign language. Researchers return her to her native jungle so she can teach sign language to the wild apes. Unfortunately, the wild gorillas like to kill people by bashing in their heads with rocks, and "as in real life, the ape language project fails" (Maestripieri, 2008, p. 62).

But while Crichton included some factual ape language research in the novel, it doesn't mean that all the science presented is correct or based on fact. Even though "Crichton mentions many real scientists' names and describes their research pretty accurately … he mixes them up with invented characters all the time, and it's not easy to tell who's real and who isn't" (Maestripieri, 2008, p. 63). Crichton discusses real scientists, and sometimes names characters after them, but gets confused on the facts and which researchers contributed which information to ape language research. Crichton also

puts ape researchers into a harsh light; "In *Congo*, Peter Elliot is described as a skilled grantsman, 'someone who had long ago grown comfortable with situations where other people's money and his own motivations did not exactly coincide … A researcher promised anything to get his money'" (Maestripieri, 2008, p. 64). Crichton's inability to accurately describe ape language research and the scientists that conducted it takes away from his credibility as an author and lessens the factuality of his scientific statements.

Crichton knows a lot about the general sleeping, eating, and grooming habits of gorillas. But his research on the animals breaks down when he delves deeper; "the accuracy of Crichton's understanding and description of nonhuman primates and their behavior begins to break down when he talks about their cognitive skills" (Maestripieri, 2008, p. 64). Crichton presents supposed real-life examples that do not have any research or data to back it up. Shile he states that there was a chimpanzee that supposedly taught sign language to her infant, there is only anecdotal evidence and no films, tapes, documented occurrences, or any other information as proof. From the very beginning of *Congo*, Crichton seems to be stretching the truth and the research to fit his storyline. Maestripieri states that "Crichton definitely goes overboard on the issues of primate dreams and their understanding of time" in addition to a lot of other things (2008, p. 66). Amy the gorilla drinks, smokes, and swears. While apes do mimic human behavior after spending time with them, Crichton takes it to a whole other level, and that level is fictional.

Congo is a science fiction novel, but Crichton does not follow the standard science fiction definition in it. He only includes specific examples and anecdotes that fit with the novel's theme and discards any other information that proves contradictory. It

seems that Crichton had an idea for a novel about apes and just threw in a few scientific tidbits to stay within the science fiction genre. If he had not been so adamant about the reliability of the information he provided, *Congo* would have been a decent piece of fiction. But in reality, Crichton wrote a poorly-researched science fiction novel because he tried to turn the facts to his purpose instead of presenting them truthfully. With *Congo*, Crichton broke the rules of science fiction that were set forth by Hugo Gernsback.

Jurassic Park

A hugely successful novel and an even bigger blockbuster movie, Michael Crichton's *Jurassic Park* is the quintessential science fiction novel. It intermingles scientific fact with fiction in order to create a storyline that compels readers because it appeals to the past (dinosaurs), the present (the cloning debate), and the future (bringing back extinct creatures). Cloning is the issue at hand in *Jurassic Park;* "Long before there was a real clone, however, there were dozens of fictional clones cranked out in dozens of novels … perhaps the most famous are the dinosaurs of Michael Crichton's 1990 novel *Jurassic Park*" (Becker, 2008, p. 69). In *Jurassic Park*, dinosaurs come back to life, "resurrected from scraps of dinosaur DNA rescued from the stomachs of mosquitoes that had been trapped and preserved in amber just after feasting on dinosaur blood some 100 million years ago" (Becker, 2008, p.69-70). Cloning had been around for over 20 years by the time Crichton wrote about it. Dolly the sheep was the first famous clone, but she was by no means the first. That honor belonged to John Gurdon, who "cloned several frogs in 1966" (Becker, 2008, p. 70).

Crichton was ahead of his time with *Jurassic Park.* Published in 1990, it was not discovered until 1994 that it was possible to get DNA out of dinosaur bones. And in

1996, an international team of researchers "published an article in *Science,* a prestigious, peer-reviewed scientific journal that does not generally publish the work of crackpots, showing that amber is indeed an excellent preservative for ancient DNA" (Becker, 2008, p. 72).

The problem with *Jurassic Park*, and with cloning in general, is that scientists need a whole nucleus, not just naked DNA to clone creatures. But "Crichton's dinosaur cloners got only patched-together scraps of DNA, not any complete nuclei" (Becker, 2008, p. 74). While Crichton provides his cloners with a sequencing machine to "patch [the dinosaur DNA] together with snippets of DNA from living species … sequencing machines generally need more DNA than you would be likely to get out of a mosquito stomach that has been sitting in amber for millions of years" (Becker, 2008, p. 74-5). The other issue is that "you have to know something about the sequence of the DNA" before you can amplify the DNA and fill in the missing spots (Becker, 2008, p. 75). But even Becker admits that this credibility gap can be overlooked. This can be attributed to scientific speculation – Crichton's practice of filling in the dinosaur DNA with the DNA of living species has not been proven, but it also has not been disproven. Thus it is speculative science that is still acceptable in science fiction novels.

The cloners in *Jurassic Park* fill in the dinosaur DNA gaps with frog DNA, which was a great idea on Crichton's part. Amphibians "may have the ability, under certain circumstances, to change their sex" (Becker, 2008, p. 76). This happens in the novel, setting up the story for the dinosaurs and their offspring to overrun the island. The cloners had purposefully created all female dinosaurs so they could not reproduce, but because of the frog DNA, they are able to change their sex and reproduce. Crichton's in-

depth knowledge is on display here; he knows that amphibians have the ability to change their sex and uses that as the catalyst for the dinosaurs overrunning the island.

Another scientific fact that Crichton gets right in the book is Chaos Theory. The character of Ian Malcolm, a mathematician, describes it as "tiny changes in the initial conditions can lead to enormous variations in the final result, and seemingly simple systems can produce complex behavior" (Becker, 2008, p. 79). Becker has no problems with Crichton's description of Chaos Theory; her only complaint is that he does not include enough of it and how it could have been applied to the plot twists.

Perhaps Becker's most intriguing insight is this; "[Crichton] seems really hostile to science and to many of the people who practice it ... the real focus here is that cloned dinosaurs ran amok, and the scientists who cloned them sold their services to the highest bidder without considering whether the project was advisable or not" (Becker, 2008, p. 82-3). But it is hard to believe that Crichton, a man who spent his entire life in the world of science, first getting an M.D. from Harvard Medical School and then writing science fiction for four decades, would spend all of his time writing books about a subject he hated. Instead, what Crichton tries to do through his novels is criticize the "commercialization of science," which can be seen in *Jurassic Park* as well as in *Congo* (they were not really trying to teach wild apes sign language, they were searching for a lost city of gold) (Becker, 2008, p. 84). Due to his death in 2008, we do not know Crichton's intentions, but "he makes a good case for increased government funding—and therefore oversight—of science…it might mean less mining of the natural world and more study of it" (Becker, 2008, p. 84).

Becker points out that "the plot line of *Jurassic Park* makes use of one of the central facts of life, at both the individual level (embryonic development) and the population level (evolution): it is not predictable" (Becker, 2008, p. 78). This is one of the reasons science fiction is so appealing; "the foremost reality that science fiction deals with is change, which could be the reason for the growing interest in the genre in the twentieth century" (Pohl, 1994, p. 61). Scientific knowledge continues to expand on a daily, even hourly basis. This is the appeal of science fiction, and it is the appeal of *Jurassic Park.* No matter the amount of planning, something will change and throw off the plans. Combine that with the public's fascination with dinosaurs and a best-selling science fiction novel will be produced. Michael Crichton's science in *Jurassic Park* might not always be factual, but it is not always fictional either. In *Jurassic Park,* Crichton uses a lot of speculative science, but "since science fiction does tend to incorporate phenomena no one has ever experienced, writers need to take some liberties, however devoted they may be to scientific accuracy" (Pohl, 1994, p. 59-60). Crichton pulls off speculative science in *Jurassic Park,* and two decades later, audiences are still intrigued.

Prey

Michael Crichton published *Prey* in 2002, 33 years after his first novel, *The Andromeda Strain.* He was no longer in medical school and had established himself as a bestselling author. In the early 21st century, was Crichton's *Prey* as scientifically factual as his first novel had been in 1966?

Prey is about nanoparticles, basically micro-robots, escaping from a laboratory in Nevada. While out in the desert, the nanoparticles quickly adapt to conditions, learning

to feed on the flesh of mammals to survive. They become solar-powered and self-reproducing. The swarm considers it their mission to destroy the scientists that created them, so much of the novel focuses on the laboratory where the nanoparticles were created. With the mutation of the nanoparticles, Crichton has already addressed one of the faults with *The Andromeda Strain*. The fact that the Andromeda strain could not adapt to its environment was a point called out by scientists. But the *Prey* nanoparticles are able to thrive outside of the sterile lab environment and change their behavior to adapt to the conditions.

Once again, Michael Crichton did in-depth research on his topics, artificial life and nanotechnology; "in popular fiction, the most notable recent depiction of nanotechnology has been in Michael Crichton's *Prey*" (Gordon, 2009, p. 472). Crichton focuses his entire book around the ideas presented by the pioneer of artificial life, Chris Langton.

> The *big* claim is that a properly organized set of artificial primitives carrying out the same functional roles as the biomolecules in natural living systems will support a process that will be 'alive' in the same way that natural organisms are alive. Artificial Life will therefore be *genuine* life—it will simply be made of different stuff than the life that has evolved here on Earth (Langton, 1989).

That "different stuff" was Crichton's point in *The Andromeda Strain* with the crystalline organism, and the "different stuff" comes into play again in *Prey.* These nanoparticles are living, but they are compromised of "different stuff" than we usually see in living organisms. As Yaeger points out, this is exactly what Crichton focuses on; "this is the core and perhaps most significant premise Michael Crichton posits to develop the deadly adversary in his novel *Prey*: evolving, self-reproducing swarms of nanoparticles that get cleverer and more dangerous—more *alive*—with each generation" (2008, p. 108).

Crichton builds his novel off of Langton's claims. The nanoparticles in *Prey* are alive, even if they are not the kind of living thing that is encountered on Earth.

Yaeger goes into great detail about what facts Crichton included in his novel. Yaeger even states that Crichton implies other artificial life theories in *Prey* but does not discuss these other theories outright. That is the mark of a good author—one who does so much research that they understand the topic and can write a science fiction novel without it feeling like a science lesson. Yaegar states "Crichton did do his homework on this; that reference section is pretty impressive … In writing *Prey,* Crichton drew heavily on key insights from the field of ALife. In particular, his intelligent and predatory swarms are based on a number of central premises, almost all of which inform and are informed by ALife research" (2008, p. 112). Crichton even discusses ideas that are fairly recent to the field; "Crichton posits the possibility of digital, artificial life, of a particularly unique and interesting kind, in his nanotech swarms. The study of such lifelike and biologically inspired processes in computers is … a relatively new scientific discipline" (Yaeger, 2008, p. 109).

But as much as Crichton does right in the book, he also does things wrong; "[Crichton] unfortunately gets a fair number of the scientific details wrong … he stretched (some would say broke) the truth, and perhaps tried to intimate a greater degree of scientific authenticity than the book deserves" (Yaeger, 2008, p. 112). Perhaps the most important point that Crichton gets wrong is the way in which the nanoparticles are eventually destroyed. Crichton wrote that the nanoparticles were designed so that they could function without the original assemblers and bacteria that created them. But as Yaeger points out, "the grand, dramatic conclusion depends on these bacteria being

destroyed by a phage (a virus that invades bacteria) … So, in theory, the benign swarms infesting humans could have lost their bacteria and kept right on functioning" (2008, p. 114). That was a gigantic mistake on Crichton's part. He first says that the nanoparticles do not need the bacteria to survive, but his conclusion rests on a bacteria-killing virus to wipe out the swarm. This was not just a case of getting the scientific facts wrong; this was a plot mistake that could have been the downfall of the entire novel. Luckily for Crichton, no one seemed to notice except for the scientists that actually study artificial life.

But even with Crichton's enormous plot and scientific hole, the real question is whether the details that Crichton gets wrong in *Prey* are even important to the average reader; "there are details here that one can definitely quibble with, but by and large the ideas are sound. The use of gene-tailored bacteria in the manufacturing process is more than reasonable and is a technology that, though still in its infancy, is growing by leaps and bounds" (Yaeger, 2008, p. 113). So while readers can learn science from the novel, Yaeger cautions them not to take it too seriously; "While Crichton's novel *Prey* draws on some of the most exciting and profound areas of scientific research in the world today, and I'm perfectly happy to let him get away with some inaccuracies in order to get on with the story, those scientific details do matter out here in the real world and the scenario he describes is really not one you should lose any sleep over" (Yaeger, 2008, p. 129-130). But just because *Prey* is about nanotechnology doesn't mean that it addresses all aspects of it; instead Crichton "focuses on the negative potential of nanotechnology" and ignores the other end that already impacts our daily lives (Gordon, 2009, p. 472). Readers who learn about nanotechnology from *Prey*, "may either not notice the intrusion

of nanotechnology into cosmetics and similar low-level innovations or may not recognize that the existence of better eyeliner today does not imply flesh-eating cameras tomorrow" (Gordon, 2009, p. 472). Crichton focuses on the dramatic issues of nanotechnology (which may or may not be possible) while ignoring how it has already taken hold in our daily lives.

Crichton's novels leave readers feeling entertained, but more importantly, the readers feel like they have learned something, and they have. After analyzing essays from *The Science of Michael Crichton: An Unauthorized Exploration into the Real Science Behind the Fictional Worlds of Michael Crichton*, it can be determined that Michael Crichton followed the baseline established by Hugo Gernsback that science fiction is "a charming romance intermingled with scientific fact and prophetic vision" (cited in Westfahl, 1998, pp. 38-39). While not everything is scientifically factual, and some facts are presented in a negative light, Crichton does base his novels in truth and real scientific theories. His novels teach readers about science and cutting-edge scientific developments. Crichton not only teaches science, but he often warns readers about what can happen if science and technology get out of control. Often his "prophetic visions" came true, though sometimes, as is the case with *Prey*, they are not actually possible. But that is why they call it "science fiction." There is fact in Crichton's novels, but it is always mixed with fiction to make the story more exciting.

Chapter Three: Science Fiction Learning and Retention

Science fiction is able to introduce new generations to science without the hindrance of textbooks, teachers, and classrooms. There are many reasons why people learn from science fiction. One of the main reasons is that science fiction takes the high-level technical language commonly found in scientific papers and puts it into a format that can be easily read by everyone (de Solla Price, 1976). Instead of having to sift through the density of a technical article, readers can learn about the newest technological inventions by opening up a science fiction book or magazine. As Gregory & Miller (2010) wrote, "science fiction as a genre in its modern form had grown out of the dramatic technology and intellectual developments of the late 19th century" (p. 30). There were so many technological achievements that a form that was easily understood by all was needed to communicate these achievements to the public.

This was the goal of Hugo Gernsback. Gernsback "believed that what he called 'scientifiction' [science fiction] served a socially useful purpose. It would, he thought, educate its readers in scientific facts, and inspire them to researches and inventions of their own" (Pohl, 1994, p. 58). Fueled by Gernsback and his *Amazing Stories* magazine, science fiction "became an experience of science for those who had the right spirit, caught all the nuances of the scientific genre, but who might not have the actual scientific experience nor even the education and abilities" (de Solla Price, 1976, p. 41). Gernsback prided himself on the technological accuracy of his stories and the ones he included in his magazine; "there was nothing 'mere' about the science in Gernsback or Verne science fiction. Rather, it was the fiction part that was relatively unimportant, though it did

provide a lot of exciting action" (Pohl, 1994, p. 58). Fiction was merely the gateway that Gernsback and other science fiction writers used to bring science and technology to the masses. As de Solla Price said, science fiction "became an experience of science for those who had science in their bones but not always inside their heads" (1976, p. 41).

People learn about the world from a multitude of sources, and that includes fiction; "learning may also result from exposure to non-educational sources that happen to contain information about the world … as such, fiction is potentially a source of information" (Marsh, Meade, & Roediger, 2003, p. 519). Negrete (2003) emphasizes the importance of using alternative methods (science fiction novels, television shows, and movies) to communicate scientific information. He states that "science textbooks have been in a privileged position over other media in science education" but emphasizes the fact that literary works "could be successfully used to communicate science not only to children or scholars but also to the general public" (Negrete, 2003). The real challenge to science communication "is to establish a bridge between science and the general public. To this end it is necessary to translate science into some common language that allows the reader to become interested and excited about scientific information" (Negrete, 2003). The reason that the general public learns a great deal of scientific information from fiction is because the authors of science fiction make it easy to understand. As McLeod says, "the very minimum that written sf [science fiction] does is to popularize the rhetoric of science, and make the language of science familiar to the reader. It valorizes and validates interest in science, and stimulates thought about the consequences of new discoveries and of new applications of science" (2010, 174-5). Negrete emphasizes that

"the results of the studies performed … suggest that science can be learned through literary stories" (Negrete & Lartigue, 2010, p. 104).

One of the reasons that people learn from science fiction, and any fiction for that matter, is because they can relate to it. Readers might list a number of reasons why they might remember information from fiction: the novel had a really good storyline; the characters were well-developed; the popularity of the novel causes people to remember it better, etc. But perhaps the most important part of fiction retention is that "people's understanding and memory for stories is influenced by their prior knowledge and experience" (Stanhope, Cohen, & Conway, 1993, p. 241). Readers are able to relate to stories because they can identify with the characters, places, and plots. In their study, Larsen and Seilman (1988) had readers "mark either a fictional or an expository text … when a memory occurred during reading" (Oatley, 1999, p. 109). The researchers found that "twice as many memories in which the reader was personally involved as an actor occurred with the fictional text as with the expository one … this kind of reminding provides the basis of a personal resonance between themes of a story and those of the reader's life" (Oatley, 1999, p. 109). The reader's experiences shape their view and subsequent retention of, and relation to, the novel. "Because of increased integration of story ideas with previous beliefs" held by the readers, fictional stories are more likely to bond with a person's memories and beliefs and stay rooted in memory (Gordon, 2009, p. 471). Marsh, Meade, and Roediger state "integration of facts from fiction would mean that readers link these facts to preexisting world knowledge" (2003, p. 520). But according to Gerrig and Prentice (1991), readers create "hybrid" representations of information from fiction after reading and do not completely integrate the facts that they

learned from fiction. The readers remember the information and believe it, but they are always on the lookout for other materials that refute the claims made in science fiction. Readers "do appear to be monitoring the text for accuracy … thus there may be limits on which information from fiction is integrated with related world knowledge" (Marsh, Meade, and Roediger, 2003, p. 520).

Another reason that readers learn from fiction and relate to the facts presented is because "our information gathering is more casual" (Gordon, 2009, p. 470). Readers do not want to read scientific journals for information about nanotechnology; they learn more about it from television, movies, magazines, and novels (Gordon, 2009, p. 470-471). A narrative is a series of casual links, which is why readers are drawn to it as a source of information (Gordon, 2009, p. 471). But "it is not only the nature of a narrative as a series of casual links that gives fiction its persuasive power. Our response to a well-told story can draw us away from the real world—and we bring some of what we have learned back with us when we return" (Gordon, 2009, p. 472).

Learning from fiction and retention of the facts presented in it can find its roots in the phenomenon that Appel and Richter call "transportation." Transportation is, in effect, getting lost in a book; "*transportation* means that readers undertake a mental journey into the fictional world of the narrative" (Appel & Richter, 2007, p. 117). The degree of transportation depends upon a reader's familiarity and previous knowledge involving the events, places, people, facts, and other details involved in the story. Because readers can relate to the story, they experience a higher degree of transportation, thus absorbing and retaining the book's information at a higher rate; but "even mild transportation can increase acceptance of assertions that readers would otherwise deliberately reject"

(Slater, 2002). The degree to which readers interact with a narrative is increased by the degree of transportation they experience, which in turn increases the likelihood of later learning and integration (Gordon, 2009). If readers get caught up in a novel, they are more likely to remember the novel and believe it as fact in their daily lives. This is true for science fiction as well as any other type of novel.

Applicable to only science fiction, a main reason readers learn and retain information is the fact that science fiction addresses "all the public and private concerns about what is happening right now, not in the future" (de Solla Price, 1976, p. 41). Basically, even though science fiction stories take place in a future world (perhaps 2050), the plots (including the science and technology) revolve around concerns of the time period in which they were written (perhaps 1950). Readers learn more information from science fiction because they already have previous knowledge on the subject and have concerns over the technology. This idea is echoed throughout articles on science fiction; "as well as a mere storytelling device, science fiction often articulates our present-day concerns and anxieties – paradoxically it is often about the here and now rather than the future" (Chown, 2008). Science fiction stories may be placed in the future, but they are really speaking to the concerns of the time period in which they were written; "many SF texts actually take place on Earth and deal with issues of immediate social and ethical relevance" (Zigo & Moore, 2004, p. 86). People are drawn to science fiction because it focuses on their current thoughts and fears of scientific evolution; "the foremost reality that science fiction deals with is change, which could be the reason for the growing interest in the genre in the twentieth century" (Pohl, 1994, p. 61). At a time when technology is growing at an ever increasing rate, "science fiction is the sovereign

prophylactic against future shock, so that if you read enough of it, nothing will take you entirely by surprise" (Pohl, 1994, p. 61).

There are many reasons why readers learn and retain information from fiction: relation to the information, previous knowledge, and transportation, among others. Science fiction takes those reasons a step further and plays on the reader's current fears about society and science. This convention leads to a higher degree of transportation because the reader has previous knowledge on the subject and the subject already occupies a portion of their thoughts. All of these reasons and storytelling devices enable science fiction to teach science to the readers and have them remember it.

Chapter Four: Implications - Using Science Fiction for Education

Science fiction has long been discussed as a way to get students and adults alike more interested in science; "literary works … could be successfully used to communicate science not only to children or scholars but also to the general public" (Negrete, 2003). Hugo Gernsback wanted science fiction to "educate its readers in scientific facts, and inspire them to researches and inventions of their own" (Pohl, 1994, p. 58). In fact, many renowned scientists and inventors have credited science fiction for first introducing them to science when they were children (Pohl, 1994).

Their names might not be familiar to the general population (though some are) but their scientific and technological advances cannot be ignored; "the honor roll of figures in contemporary science is filled with people who were addicted to science fiction in their youth" (Pohl, 1994, p. 58). Stephen Hawking has stated that he spent more time reading science fiction during his university days than he did reading his textbooks; Marvin Minsky, who has won awards for contributions to the study of artificial intelligence, credits science fiction stories for his interest in robots (Pohl, 1994, p. 58). Nobel Prize winners, such as Steven Weinberg, credit science fiction for their interest in science; "I went from comic books to science fiction, which probably was as important as anything else in getting me interested in science" (Pohl, 1994, p. 58). Perhaps the most startling realization is that scientists have been testing science fiction inventions and theories and using them in real life. Leo Szilard "partly credits H.G. Well's early science fiction story about atomic energy, *The World Set Free,* with the inspiration that led him directly to the Manhattan Project" (Pohl, 1994, p. 58). Science fiction stories also encourage national

programs at large; would NASA and space exploration be as heavily funded if a fair amount of science fiction novels did not focus on alien life and humans living on other planets? Probably not. These are only a handful of scientists and scientific ideas that have been influenced through science fiction. It can only be imagined that if these great scientists were science fiction fans first, there must be unlimited, untapped potential in today's classrooms waiting to be introduced to science.

Imagination and creativity have always been qualities lauded by parents, teachers, professors, and psychologists. In order to develop these faculties, students must be given tools to open up their brains to new ways of thinking; "science fiction provides many vehicles for inculcating those tools in a variety of subjects by stimulating and thus motivating students to learn" (Ontell, 2003, p. 57). Especially when textbook material is sometimes so dense and boring that students simply give up on reading and learning, science fiction can make it fun again; "quite often one needs more than the traditional teaching tools in order to explain complex scientific theories to students" (Negrete, 2003). To engage students and make them interested in science, "it is necessary to translate science into some common language that allows the reader to become interested and excited about scientific information" (Negrete, 2003).

Negrete conducted a study that is "very much in support of N. Gough's (1993) plea for more diversity in the communication resources used in science education" (Negrete, 2003). Negrete's study focused on a group of university students and tracked whether they learned scientific information better through textbooks or through short stories. The researchers concluded "the results of the studies performed … suggest that science can be learned through literary stories. In particular, [the results] suggest that

narrative information is retained for lengthier periods … and that narratives constitute an important means for science communication to transmit information in an accurate, memorable, and enjoyable way" (Negrete & Lartigue, 2010, p. 104). Participants even gave verbatim quotations two weeks after reading the story, suggesting that "people retain information when it is presented in an attractive way. Apparently, the literary effects … enable emotions to be invoked in the reader and, therefore, information linked to this emotional response more memorable" (Negrete, 2003). Since narratives are presented in an attractive way, science fiction stories could have better retention rates in the classroom over traditional textbook formats, and Negrete's and LaLartigue's 2010 provided evidence to support that curriculum change.

Learning about the most effective way to communicate scientific information can have serious implications on the way that students are taught science; "it is a given that the science postulated in science fiction can be a source of lessons and discussions in Science classes" (Ontell, 2004, p. 64). But science fiction, writing it as well as reading it, can be used to teach a variety of other subjects and skills as well. Learning to write science fiction will "promote creativity and the desire to try innovative writing and problem solving," skills that are valued not only in students but in the professional world as well (McCarty, 1998). Other important skills such as research skills and the ability to think critically can also be promoted through introducing science fiction to the classroom and linking it to relevant research (Kilby-Goodwin, 2010, p. 60). A classroom project implemented by Kilby-Goodwin on this very idea had students and their parents expressing "a great deal of enthusiasm … Students enjoy being able to read books they

are already interested in for class and linking them to researchable ideas such as time travel, invisibility, and even video games and text messaging" (2010, p. 62).

As Zigo and Moore describe, "science fiction holds virtually untapped potential as a means for teaching students to read and think critically" (2004, p. 85). Kilby-Goodwin's project is just one way to do that. Technical writing can also be taught through science fiction. Science fiction follows the "sci-fi method, the orderly system of information gathering and theory formulation that distinguishes science from random anecdote" (McCarty, 1998). By researching and writing about a technical idea using the sci-fi method, students can learn how to accurately and easily communicate technical information. This can be a good influence for future essays revolving around technically dense information. Technical writers often have to communicate technically dense information to the general public. Students can understand how Crichton made technology and science accessible for all education levels through his writing and his science fiction novels. That is exactly what technical writers have to do – make scientific and technical information understandable to all. More students could become interested in technical writing, communication, engineering, science, and many other careers because of their introduction to science fiction in the classroom.

Science fiction does not have to be confined only to science classes. Michael Crichton's novels, which have been analyzed to show that they do contain actual scientific information, could be used for other coursework as well to teach science, reading and writing, as well as research, critical thinking, and analytical skills. There is a vast amount of untapped potential regarding the use of science fiction in education. But teachers must take it upon themselves to analyze science fiction texts to determine

whether the information is factual. It is up to educators to open their minds and change their curriculum to make learning more exciting and interesting for students.

Chapter Five: Conclusion

There are always arguments against using non-traditional texts in a classroom setting. Novels may present the time period correctly but portray the beliefs of the people incorrectly. Biographies may be biased in one way or another, including or leaving out facts that make the subject look better or worse. But the truth is that students sometimes need non-traditional formats in order to learn information instead of always reading out of a textbook or listening to a lecture (Negrete, 2003). Non-traditional texts like science fiction novels, especially those by Michael Crichton, do contain factual scientific information that can teach theories and facts to students as well as the general public. Readers can even remember information from novels better than the information that they read from textbooks because of conventions such as transportation and relation to the subject or characters.

Science fiction novels do contain scientific information, and this information can easily be learned by the readers. Of course, the readers do need to keep in mind that they are reading fiction so some points may be exaggerated, but that does not mean that the whole novel is false or that the ideas presented are implausible. The science is real and can be remembered and retained by readers for long periods afterwards. In addition, science fiction novels would be a great addition to any classroom. Non-traditional teaching techniques are not only fun and allow students to use their imaginations, they also teach science and promote skills such as research, analysis, critical thinking, and writing in the students. Science can be learned in so many other ways than just through a

textbook. The curriculum of many classes, science as well as other subjects, should be re-examined to include more science fiction novels in their syllabi.

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