

TEACHING SCIENCE WITH SCIENCE FICTION

by

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ABSTRACT

The focus of this action research project was to determine how using science fiction reading material could impact student learning at the high school level. Specifically, will using science fiction increase levels of student engagement, reinforce science content learned in class, increase science literacy skills, and finally to determine if there will be an increased interest in science related careers. Students were introduced to science fiction reading material along with regular content. The methodology continues with the students collaborating and developing their literacy skills using short pieces of science fiction with writing prompts and research questions. The final portion of the treatment consisted of the students reading a science fiction book, researching the science concepts within the text, then presenting the project to their peers.

The data analysis incorporated several pieces of quantitative and qualitative evidence. These include student pre and post attitudinal surveys, student work samples of written responses, personal interviews, and rubric based presentations. The data was collected from three different classes; Earth Science ($N=8$), Biology ($N=10$) and Chemistry ($N=8$). The data revealed the lower level Earth Science had the most decreases in interest for science reading and pursuing careers in science, as opposed to the Biology and Chemistry classes showing increases in interest in both areas. All of the classes demonstrated increases in abilities for science research and performance on the student presentations indicate science literacy increased as well. Overall there was a positive response from students with regards to levels of engagement and achievement.

INTRODUCTION AND BACKGROUND

Summit Preparatory School (SPS) is a year round therapeutic, private, boarding school nestled on five hundred acres of private land in Kalispell MT. At this high school the students range in age from thirteen to nineteen years old, grade levels nine through twelve with some students taking college courses at Flathead Valley Community College. Although a few students' tuition is paid for via insurance or the state in which they live, most come from a higher than average socioeconomic background (www.summitprepschool.org). The students that attend Summit come from all over the United States and sometimes from other countries, none of the students originally reside in Montana. Currently there are a total of forty-nine students attending SPS, thirty-six male and thirteen females. Of the forty nine students the racial diversity is approximately 88% Caucasian, 10% Hispanic and 1% is considered as other. Students typically stay about fifteen months while they receive therapy, build positive relationships, improve their academics, and prepare for college. During the time that students are attending SPS they will be obtaining the required credits towards graduation as well as preparing for college.

Typical class size at Summit Preparatory School ranges from approximately ten to fourteen students with freshmen to senior level students placed by course section rather than separate classes for each grade level. Students attend school year round in twelve week blocks with a total of four semesters per year. Each semester students take three classes for seventy minutes and a study hall is integrated into their day. Each block I teach three different science classes. For the spring 2014 semester I will teach Chemistry B, Biology B, and Earth Science A.

Focus

Students at Summit Preparatory School are typically behind in credits and their academics in general. This is primarily due to circumstances in their lives that have taken priority over education and has resulted in the students coming to the therapeutic boarding school. Students that are behind in credits or are low functioning educationally will struggle to become successful in academics and often have learning gaps. Educators need to help fill these gaps, assist students in obtaining academic success, and help the students to prepare for college.

The intervention I have chosen is to utilize other forms of science related reading material in order to increase engagement in science reading, reinforce concepts, increase science text comprehension, and develop student interest in science related careers. Specifically, I will be using science fiction to answer three questions. My main research question is “In what ways will the incorporation of science fiction reading material impact student learning?” Another question I seek to answer is “Will the use of science fiction reading material engage students in science reading?” I will also be looking to see if there is an improvement in science literacy as defined by the National Science Education Standards. The next question to address is “Will using science fiction material reinforce science concepts?” Finally, “Will using science fiction encourage the development of student interest in pursuing science related careers?”

CONCEPTUAL FRAMEWORK

With the Next Generation Science Standards (NGSS) final version having been released in 2013, the stakes are high for literacy in the sciences. According to the Carnegie Corporation of New York-Institute for Advanced Study Commission on

Mathematics and Science “the nation’s capacity to innovate for economic growth and the ability of American workers to thrive in the modern workplace depend on a broad foundation of math and science learning, as do our hopes for preserving a vibrant democracy and the promise of social mobility that lie at the heart of the American dream” (2007, p 1). This equates to the idea that the future is dependent on the education within mathematics and science. Currently, only 28% of the American population is considered scientifically literate (Miller, 2007). There is an ever growing need for growth in science and technological advances, in order for the US to be competitive in this economically - challenged nation. This means that educators have an increased obligation to help our students become literate in science. What does being science literate mean? According to the National Science Education Standards:

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena.

Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (National Science Education Standards, p 22).

Project 2061 was developed through three years of research asking hundreds of scientists what science literacy means for high school students. Scientists input their thoughts on what is essential and relevant for students to “know and be able to do” (Harty, 1993). The Science for All Americans (SFAA) describes that the focus is to be less on memorizing massive amounts of facts and more on the following core concepts:

- understand how the scientific endeavor works and how science, mathematics, and technology relate;
- view the world of nature and the role of humans in it;
- grasp conceptual knowledge about science, mathematics, and technology in the context of history and the themes that cut across all fields; and
- acquire the habits of mind to be inquisitive, critical participants in the affairs of the world.

The idea here is to get away from the remote controlled responses that are merely memorized facts by our students in order to achieve a desired grade. We need to move towards the understanding and application of science concepts and how they relate to our lives.

The development of these skills lies in the hands of educators to promote interest, value, and to integrate content standards with literacy strategies. Hershey (1990) states “Science is too often taught in a vacuum and at too basic a level for the typical student. Science should be linked to everyday life and current headlines.” Students need to fluently grasp content and be able to utilize it, with a specific need in our country to become literate in the sciences. Miller (2007) claims “We should take no pride in a finding that 70 percent of Americans cannot read and understand the science section of

the New York Times” (www.sciencedaily.com, 2007). In order to alleviate this lack of science knowledge, we need to move away from covering content “a mile wide and an inch deep” (Nelson, 1999). This means that educators need to incorporate strategies that promote literacy, not just to read science but to be able to describe, predict, evaluate and take a position on issues based on evidence. Jon Miller, Hannah professor at Michigan State University states why we must become more equipped with science content “ the need for a more sophisticated work force; a need for more scientifically literate consumers, especially when it comes to purchasing electronics; and, equally as important, a scientifically literate electorate who can help shape public policy” (www.sciencedaily.com).

The increasing need to better prepare our students towards literacy skills in the sciences suggests that teachers adjust their current strategies to accommodate this need. Science text and vocabulary can be difficult to comprehend, especially to an already struggling reader. Many textbooks and teaching strategies focused on content can be rather daunting to students as they often find it boring. One way educators can alleviate this is to provide more engaging science related reading material such as science fiction. When students were asked what type of reading activities they enjoyed in school, free reading, meaning students could choose what they read, was ranked as preferential by 60% of sixth graders in a study conducted on 1800 culturally and socioeconomically diverse students (Phelps, 2005). If students are given an opportunity to have more of a choice in what they read they will find it more pleasurable and more likely to follow through. With this in mind, we as educators can provide this opportunity by incorporating multiple forms of science literature in our classroom. In particular, the use of science

fiction has merit for engaging students in reading, while reinforcing science concepts (Burford, 2012).

Many of today's technologies or science discoveries were previously dreamed up in a science fiction piece. For instance in a short story written by Mark Twain, *From the London Times of 1904*, Twain had envisioned what he referred to as a telectroscope. This device was similar to a telephone being used as the mechanism to which we now know as the internet. Another example of science fiction becoming reality was an idea proposed by Stanislaw Lem in 1961 with regards to touch screen technology such as what we have with iPads and Kindles (worldtracker.org). Many science fiction works are the precursors for new technology and scientific advances and need to be regarded as possibilities for the future rather than just fiction. Biggle (1988) claims "Science fiction is the one literature that deals with today's reality—that provides a basis for discussion and understanding of the complex events of our time. It opens doors for students—doors into all branches of knowledge" (p.125).

Science fiction author Julie Czerneda states "A love of reading produces a person who is literate. A love of reading science fiction produces a literate person open to new ideas, critically aware of the consequences of change, and ready for the future" (Czerneda, 2006 p. 42). Science fiction reading material tends to be more engaging than standard reading. When students are asked what type of books they enjoy reading, the answer is often science fiction or fantasy based. According to a poll conducted for the Young Adult Library Services Association 2011 Top Ten book list, approximately half of the 25 nominees were science fiction or fantasy related (Smith, 2012). This list shows that adolescents do read for pleasure and are interested in science related concepts,

however, they prefer fiction. If we utilize science fiction as an engaging reading experience, it can increase text comprehension, relate and reinforce science concepts being learned in the class, and develop an interest in science related futures.

There are some drawbacks to consider when using this type of fiction in the classroom. One thing to acknowledge is the lack of quantitative data that reflects using science fiction to be an effective strategy. I was able to find significant qualitative data that suggests students were more engaged and seemed to be improving academically as a consequence. Author Julie Czernanda states,

When students read a good science fiction story, they are entertained. But as you guide them deeper into the science “what if” that lies beneath the story, they learn to explore scientific concepts with a critical eye, to see the importance of context and source, and to recognize potential issues (Czernanda, 1999).

During the annual American Association for the Advancement of Science (AAAS) meeting held in 1998, the topic of discussion was the use of science fiction as a strategy, and that it just may “rescue” the teaching of science. “Dubeck has found that by teaching students through science fiction instead of traditional techniques, students gain a better understanding of the scientific principles” (Physicsworld.com). Dubeck provided the following examples: *The Day the Earth Caught Fire* and *2010* were used as way to demonstrate physics concepts. He also used “*Star Trek: the Next Generation* to explain the Greenhouse Effect, and *Star Wars* to discuss the physics of outer space” (Physicsworld.com).

Another thing to consider when using science fiction is that it may be regarded as fantasy or pseudoscience. One of the purposes of this intervention is to have students

delineate between what is truly fiction, what are the underlying science concepts, and what may be possible in the future. For instance, Jurassic Park (excerpt in Appendix C) written by Michael Crichton in 1990, describes DNA extraction of extinct dinosaurs preserved in amber and used to re-create dinosaurs. Many of the aspects within this piece of fiction are accurate with regards to the cloning of extinct animal DNA currently being conducted in research lab facilities. While some of the aspects of the book are inaccurate, others may be possible in the future but science just isn't there yet. The goal is for the students to learn to evaluate the fiction and apply the content information accordingly.

One last thing to consider is the nature of the science fiction. Some of the stories may depict violence, foul language, or sexual references. I will alleviate the inappropriate texts by previewing and hand selecting the options from which the students will choose from. Also in doing this I can make sure that the fiction they read correlates to class content.

METHODOLOGY

The primary goal of my Capstone Project is to discover how the use of science fiction reading material will impact student learning. The idea is that utilizing more interesting text to read along with the required text, the students will become more engaged leading to a positive change in attitude towards science, science literacy, reinforce content, and to develop interest in science related careers.

This treatment was conducted with a total of twenty six students ranging in grade levels of ninth through twelfth. The Earth Science A class consisted of four freshmen and four upper class students ($N=8$). Two of the students were re-taking this course to improve their grade. My Biology B class was of sophomore and junior level students

($N=10$) and the Chemistry B class consisted of junior level students with one student taking the course for a second time ($N=8$).

The intervention was conducted over a four week period beginning the end of February and ending in March of 2014. Using three different levels of classes and science background will gave me a more diverse student body with varying levels of ability and allows for the results to have a generalizability component. The study was consistent during the four week period and was in addition to their normal coursework to determine if using fiction helped reinforce class concepts. I compared the data of this intervention between the three varying classes to see if the treatment had different results depending on science background.

The treatment plan will began near the beginning of the twelve week semester. The introduction of science fiction reading material began during the first week of content learning. I started the intervention by providing short pieces of science fiction and assigning the students into groups with a guided reading sheet that has questions pertaining to the reading. These questions included writing prompts that ask students to analyze themes, describe and evaluate science concepts within the text and to engage in group collaboration. This portion of the process was designed to get the students interested and help them look for meaning, science themes, and to relate to the relevant content they are currently learning. An example piece of science fiction can be found in Appendix C with the questions and writing prompts in Appendix D.

Two of the three classes were assigned a specific book chosen to go along with class content, while the third class was able to choose their own piece from my collection or the school's library. I decided to utilize *Journey to the Centre of the Earth* by Jules

Verne to go along with the Geology portion of my Earth Science class and *Frankenstein* was chosen to go along with the Electrochemistry portion of my Chemistry class. My Biology class was able to choose their own as long as it was Biology related. The students had two weeks to read the book independently, however I allowed them at least thirty minutes of class time per week for reading. I provided a reading guide/concept log (Appendix E) with questions that will ask the students for specific information such as; plot, characters, setting, terminology, emerging themes, etc.

The third and fourth week of the treatment plan contained a research component. Students were required to research the science being conveyed in the reading material that they chose. They were allotted three class periods in the computer lab to investigate the science and technology within the fiction, if that wasn't sufficient time students had to finish during their study hall time period. Specific guidelines in rubric form were provided to lead them in their research (Appendix F). The final portion of this treatment was for the students to present their research to the class formally.

The treatment plan began with a student attitudinal survey (Appendix A) regarding their attitudes towards reading science related text. This helped to determine their level of comfort with reading, specifically in science, and their level of interest. At the end of four week treatment, I conducted the post survey to determine if there has been a change in attitude toward reading science text, interest, or if they feel they have an increase in abilities. After the treatment, I conducted student interviews (Appendix B), with three students per class to discover their thoughts about the intervention and whether or not they thought it was useful for their academic success, increased interest in science

related careers, and to see if they've made connections to content and current science research.

I began the science fiction unit by utilizing student collaboration with short pieces of science fiction reading material (Appendix C) and had the students use guided questions (Appendix D) to assist them in relating the material to the content they are currently learning. This was used as a precursor to help the students learn to dissect the science fiction piece to look for specific content. The collaboration portion was used to generate a group discussion and to develop a written summary. A rubric score was used as a basis to evaluate the depth of their answers as related to literacy and content reinforcement purposes. I used a zero to two point score to determine how well the students were able to utilize the evidence provided in the short pieces of introductory science fiction (Appendix C). The scale is as follows; zero points were given for no response or an irrelevant answer that doesn't pertain to the question, one was given if the student gave some basic information with a minimal but acceptable answer, and two was given for an answer that was a clear, thorough response that indicated the use of at least one reliable source. I used this scale to rate questions one, two, and five of Jurassic Park, on the first page of questions (Appendix D). Questions three and four were not scored as they were used to evaluate prior knowledge about vocabulary and science as it may pertain to the story. The same scale was used for all of the questions for the Thiotimoline to the Stars piece.

The final piece of data is the rubric (Appendix F) that was used during their final presentations of the book. I used this to look for links from their research to current and historical science as compared to the book they chose as well as their ability to relate it to

the content taught during that time. This rubric was used to determine if using science fiction helps reinforce key concepts, decipher to what extent they could evaluate and analyze their book, and their ability to present the information to their peers. See Table 1 for data triangulation matrix.

Table 1
Triangulation Matrix

Focus Question: In what ways will the incorporation of science fiction reading material impact student learning?			
Subquestions	Data Source 1	Data Source 2	Data Source 3
Will using science fiction reading material engage students in science reading?	Student pre-survey on attitudes toward reading.	Post survey on attitudes towards reading.	Student interview to determine students' perceptions on their own skills before and after the reading.
Will reading science fiction material reinforce science content?	Collaboration summaries (student work samples)	Guided reading and concept logs	Student presentations of their book and research (rubric based)
Will using science fiction increase or develop student interest in pursuing science related careers?	Pre-survey	Post-survey	Student interviews
Does the use of science fiction reading material increase science literacy?	Student work samples	Writing prompt quizzes	Student presentations

DATA AND ANALYSIS

A variety of data was collected in order to obtain both quantitative and qualitative results in four specific areas. Student attitudinal surveys were given prior to and after the

treatment to determine if using science fiction was engaging material and to see if it promoted an interest in science related careers. Personal interviews with students were also used for that purpose. Collaboration time, writing prompts and student presentations were used to determine if the treatment helped to reinforce class content or increased science literacy.

Impact of Reading Science Fiction on Student Engagement

Questions one and two on the student attitudinal survey (Appendix A) were used to compare levels of engagement before and after the treatment with regards to reading and specifically reading science material. Seventy five percent of my Earth Science class ($N=8$) reported no change in opinion when asked if they enjoyed reading. Thirteen percent of students revealed an increase of general reading enjoyment after the treatment and another 13% reported a negative change in opinion. The second question asks students if they feel reading science is boring. Before the treatment 12% of students felt that reading science was boring most of the time, 68% felt that it was boring occasionally, 28% indicated rarely as their opinion and the remaining 25% said not at all. Sixty three percent of students in this class showed no change in opinion after the treatment, while 25% percent had a positive change in opinion for science reading and the remaining 13% indicated a decrease in their opinion of reading in science.

The Biology class ($N=10$) reported that 70% of students enjoyed reading in general occasionally and the other 30% reported they enjoyed reading most of the time prior to the treatment. There was a shift in opinion after the treatment. Twenty percent of students showed a decline in the enjoyment of general reading going from occasionally down to rarely. Forty percent reported no change while the residual 40% indicate they

enjoy general reading most of the time, up from 30%. For question two prior to the treatment, 10% of students indicated that reading in science was not boring at all, 20% reveal they rarely find science reading boring, 50% indicate it is occasionally boring while 20% said it was boring most of the time. Results after the treatment show that 10% of the students still felt that science reading was not at all boring. Thirty percent of students felt it is rarely boring, up from 20%. Fifty percent of students report no change in opinion and remain at occasionally boring. The final 10% report feeling that science reading is boring most of the time, down from 20%.

When my Chemistry class ($N=8$) was asked question one, the following was revealed. Twenty five percent enjoyed reading most of the time prior to the treatment while 38% reported the same answer after resulting in a net increase of 13%. Another 25% enjoyed reading occasionally prior to the treatment and felt the same after. Fifty percent indicated that they enjoyed reading rarely prior and a decrease to 38% after the treatment. Question two reports that 13% of students find science reading boring all the time before and after the treatment. Fifty percent indicate that it is boring occasionally prior to treatment and this remained constant after. There was no net change for the rarely and not at all boring opinions as they remained at 13% each after the treatment.

Student interviews ($N=9$) revealed a 100% positive response when students were asked if reading science fiction made reading more fun or interesting. One student remarked “Yeah I think so. It was cool to read a book like that where science and fiction cross over.” When students were asked if reading this material increased interest in science or reading and writing in science, 89% of students responded yes. One student claimed, “I think it increased my interest. I’ve never read a science fiction book, much

better than reading the text.” Another student remarked, “It did, it increased my interest in rocks and want to know more about the science in getting to the center of the Earth.” When asked if using science fiction in the class was a productive use of time, 89% of the students indicated that they thought it was useful. One student said “yeah because the computer lab time and ideas presented in the book helped me research a lot.” Of the remaining 11%, one student reported “There could’ve been other things that would’ve been a better use of time, but it was interesting and I enjoyed it.” Seventy eight percent of students had a positive response when asked of their overall opinion about reading science fiction in our class, while 22% felt it was not needed.

The student attitudinal surveys reveal only a slight increase in interest for reading science material in the Earth and Biology classes. Most of the valuable input comes from the student interviews that indicate a positive response towards reading science fiction. The majority of the responses from these interviews reveal an increase in student engagement for all three classes.

Impact of Science Fiction on Reinforcing Content

The scores from the collaboration writing prompts were used to determine if using science fiction reinforces science content. Question one from the Jurassic Park writing prompts (Appendix D) asks the students to briefly describe the plot and setting. Eighty percent of students in my Biology class ($N=10$) were able to fully describe what is occurring in this portion of the story and were able to briefly describe the science of the DNA sequencing being conveyed. An example from one student “The people being shown around the lab where the extraction of DNA is in. They then see a supercomputer that decodes the DNA and splices the DNA so that it is complete.” The other 20% gave a

minimal answer that only mentioned DNA such as this answer from one student “they are in a secret laboratory and they are talking about DNA.” Sixty percent of students made a reference to the DNA sequencing machine and briefly described its use in question two while the other 40% only mentioned the machine. Question five asked the students about the science being conveyed and about the student’s familiarity of the topic. Eighty percent of the students scored the maximum of two points by making references to gene splicing and cloning while the other twenty percent had a score of one indicating a basic understanding of the science being conveyed but did not offer an explanation.

The second part of this assignment was conducted in the computer lab with guided research questions (Appendix D). The questions were designed to guide students toward factual evidence when analyzing the Jurassic Park excerpt (Appendix C). When asked how long will DNA remain un-degraded in amber and to describe what un-degraded means, 60% of the students were able to answer the question with a score of two while the other 40% only answered part of the question resulting in a score of 1 meaning that they gave very minimal answer as compared to answers that scored two points. Question four asks about separating dinosaur DNA from other animal DNA from the mosquito’s blood. Twenty percent of the students were able to fully describe the extraction process and scored two points while the other 80% scored 1 point by mentioning physical extraction and separation. When responding to question six, How do you know which parts and how much of the dinosaur genome is missing and what to replace it with? Fifty percent of student responses earned a score of two, 40% earned a score of 1, and 10% of the responses earned a zero score. For example, a response that earned a score of two “if there are genes missing from the DNA code and filling it with

similar animal DNA.” Question eight asks the students to explain why the book should be called “Cretaceous Park” rather than Jurassic Park, sixty percent mentioned that some of the dinosaurs were from the Cretaceous period but didn’t provide specific types, resulting in a score of 1. The remaining forty percent of students’ responses scored zero.

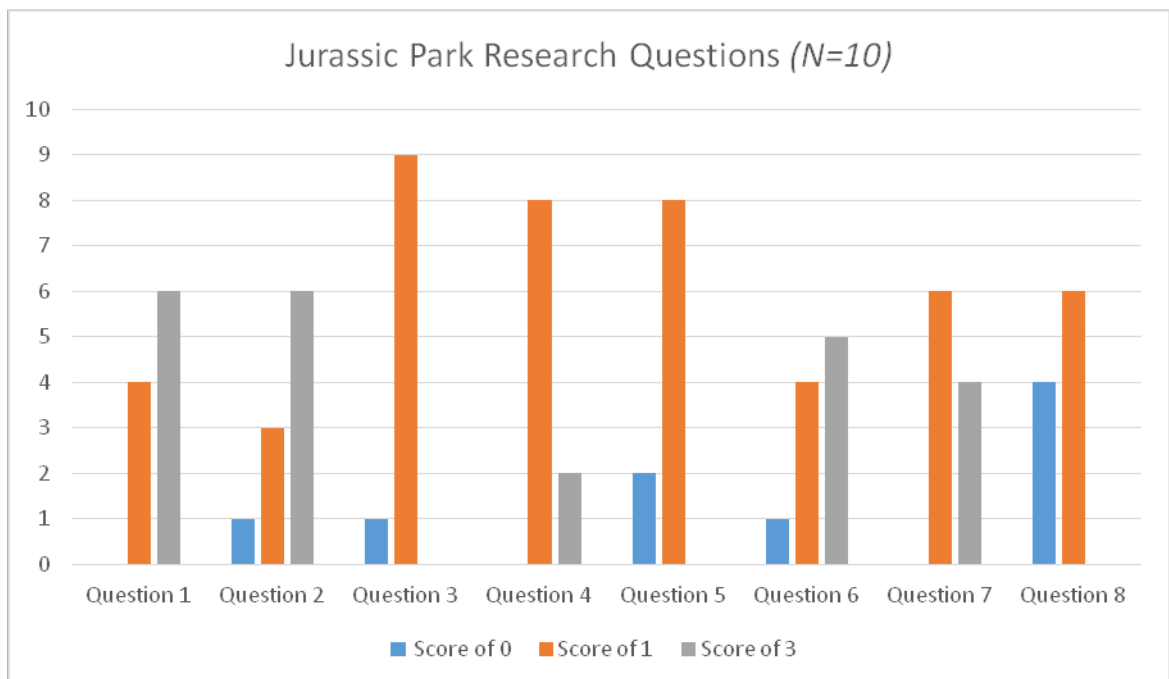


Figure 1: Guided Research Question Responses to the Jurassic Park Excerpt, (N=10).

The final portion of this assignment included a written summary of the student’s evaluation of the story. The prompt asked the students to analyze their research and determine what parts of the story are fiction and which parts are possible. I used a scale of zero to three points to score their responses. A score of zero was given for no response or a response that was irrelevant. A score of one was given for a minimal answer that used 1 piece of evidence to support their claims in which 40% of students scored.

Another 40% of students were given a score two if they provided two pieces of solid evidence to support their claim and referred back to the excerpt. A three was given to 20% of the students as they were able to utilize at least three pieces of solid evidence from the research and made at least one reference back to the reading. Figure 2 shows a student response that earned a “3.”

Jurassic Park could not happen with today’s technology. One point is that it would be impossible to separate dinosaur DNA from other DNA in the mosquito’s blood. And even if you could isolate the dinosaur DNA, you couldn’t clone it because the DNA strand would most likely be very incomplete. If you replaced it with frog DNA as they did in the movie, you would have a nonfunctioning dinosaur! And even all this is dependent on whether blood in an amber fossil is even from the period of time that you want to find dinosaurs from, or if there is enough blood for an accurate sample. It would also be extremely rare to find this type of fossil.

Figure 2. Example Student Writing Response.

My chemistry class ($N=8$) performed the same type of task using a short story by Isaac Asimov, *Thiotimoline to the Stars*, see Figure three. Twenty five percent of these students gave consistent answers that demonstrated a clear thorough response referring back to class content and therefore resulted in a score of two. The remaining 75% of students were able to answer the questions with basic understanding earning them a score of one.

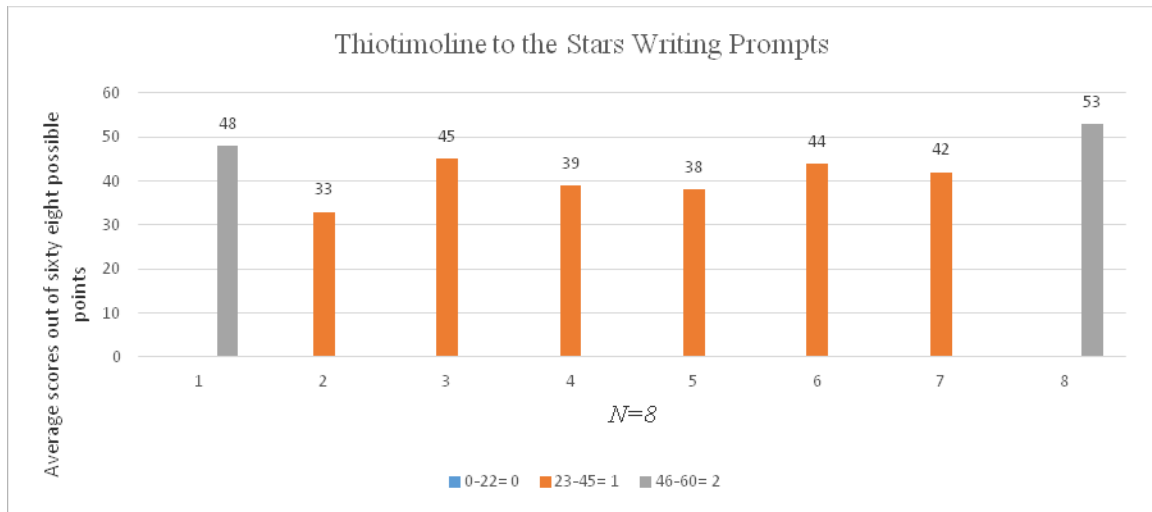


Figure 3. Average Writing Prompt Score Thiotimeline to the Stars, ($N=8$).

Student interviews reveal that 78% of students ($N=9$) felt that using science fiction in the class helped them to increase their abilities and/or achievement in class. One student claimed “With Thiotimeline I understood more concepts because it made us talk about it and learn it.” The other 22% felt it didn’t really help them with overall achievement in the class as one student states “I don’t think so because I like the text better because I don’t do well with reading comprehension.” When asked if reading this type of material helped them to learn concepts that were expected from them in class 89% of the students reported yes. During the interview the students were asked if they could establish a connection between the reading and our current class content, all of the students were able to provide a t least one clear, concise example that related directly to content. One student responded “The Geology part, I learned it’s not possible to go to the center of the Earth. The rock parts all make sense now.”

Student work from each of the three classes indicates that students in general were able to utilize the science fiction components to relate to class content. Earth science

students were able to relate geology concepts, biology students were able to evaluate gene splicing and DNA content, and chemistry students were able to relate electrochemistry concepts. The interview process also reveals that the majority of students could analyze the fiction and non fiction components to reinforce their learning to current class content. All students were able to establish a connection from science fiction to the content being learned in class.

Impact on Student Interest in Pursuing Science Related Careers

The student interview process and attitudinal surveys were also used to determine if using science fiction in the classroom helps to develop an interest in pursuing science related careers. According to the interviews, 89% of the students responded positively to an increased interest in science, but not necessarily as a career choice. Thirty three percent of the student interviews indicate an increase in careers in science. One student states “I’m really interested with different technology and it opened my mind about the future potential.” The attitudinal surveys yielded different results based on which science class they were in. Thirteen percent of the earth science class reported that they had no interest in pursuing a career in science prior to the treatment, this increased to 25%. Fifty percent of students indicated they rarely feel interested in pursuing this type of career prior, while no students reported feeling this way after. Another 13% said they were occasionally interested before and this increased to 50% after the science fiction unit. Twenty five percent indicated they are interested in a science career most of the time, this opinion did not change.

Sixty percent of biology students reported that they were not interested in pursuing a science related career prior to the treatment, this decreased by 10%. Ten

percent of students felt they were rarely interested, this increased to 30% after the treatment. Another 20% stated they were interested in science careers occasionally and this decreased to 10%. Ten percent of Biology students reported most of the time as their response to the same question prior to and after the treatment period.

The chemistry class surveys reported very little change in opinion after the science fiction unit. Twenty five percent of students stated ‘not at all’ as their answer when asked if they were interested in pursuing science related careers, this did not change. Thirty eight percent reported rarely, this decreased to 25%. Thirteen percent claimed they were occasionally interested, and this opinion remained after the treatment. Another 25% indicated most of the time for their answer and this increased to 38% after the unit. The student surveys report various changes in this area. Overall the Earth science students indicate the most developed interest in pursuing careers in science after the treatment. Biology student show a slight increased interest from “rarely fee; interested” to “occasionally interested” which indicates the treatment may have influenced a positive change in their interest level. The chemistry surveys indicate very little change in interest overall.

Impact on Science Literacy

Multiple pieces of data were evaluated to determine if using science fiction helps increase science literacy as it pertains to the National Science Education Standards. Student surveys were used to look for changes in level of comfort before and after the treatment. According to the surveys, the earth Science students ($N=8$) revealed a decline of 38% in science reading ability and reported no net change for the ability to understand science related text. However, another 38% of students reported an increase in their

abilities to write about science and 13% increase for analyzing science related material. Twenty five percent of students felt more comfortable doing science research, while another 25% felt less comfortable. The biology class ($N=10$) yielded a 30% increase when asked of their comfort level in reading science related material and a 10% increase in ability to apply the reading. Forty percent of the students reported an increase in their level of comfort for performing science research. Thirty eight percent of my chemistry class ($N=8$) indicated an increase in ease of reading science text with no net change in understanding the material. Thirty eight percent of students indicated that it is less difficult for them to write about science while a 50% increase is reported in the ability to analyze science material to find important concepts. A 13% increase in comfort level is reported with respect to their comfort level in science research.

Student presentations were also used to evaluate literacy. Rubrics (Appendix F) were scored according to the students' ability to fully address each component. One hundred percent of the earth Science students were able to relate and link themes from their book to class content such as volcanism, rocks and minerals and the layers/composition of the Earth as it was read in *Journey to the Centre of the Earth*. All of the students were also able to compare historical research to current research and predicted that future science research would be "to drill closer to the mantle" as one student claims. Students in my biology class picked their own book so their answers varied. However, 100% of the students were able to link a theme from their book to science content they either learned in biology or in another science class. Twenty percent had Biology related themes such as DNA, cloning or Evolution. Again, 100% of the students were able to provide historical references and compare them to current science

research. Eighty percent of biology students were able to predict what future research may bring such as potential moon colonization or robots with specialized programming to make them more life-like. Fifty eight percent of chemistry students were able to discuss and link electrochemistry themes to their book *Frankenstein*. Thirty three percent referred to Galvani's experiment of the frog leg twitching via an electrical current. All of the students were able to compare historical research to current and made predictions about future research. One hundred percent of students in all classes were able to delineate between the fictional portions of each story, legitimate science and future potential science.

All students were able to perform the research component of this treatment. Students were able to evaluate the fictional portions and compare to current science research indicating they are becoming more science literate accordingly. The earth science class reveals a decrease in reading ability yet no net change in understanding the material. This data taken from surveys indicates a contradiction, therefore inconclusive as to the levels of improved science literacy. The biology class shows an increase in comfort of reading, application of the material and performing research which indicates an increase in science literacy. Chemistry students report an overall increase in all of the areas analyzed for science literacy.

INTERPRETATION AND CONCLUSION

The treatment plan that I chose provides some evidence that using science fiction in the classroom has merit as a science instruction tool. The personal interviews that were conducted provide the most insight on the students' overall perception. The majority of the students reported that reading science fiction was more interesting or fun than reading

standard text. They also responded that they felt that doing these types of activities with science fiction helped them to learn concepts and increase their abilities. There was also an increase in level of interest in science reading and writing and/or career interest in sciences.

The surveys that were conducted tended to have varying results. One thing I noticed was that the earth Science class had the most decreases in interest level of reading science material, comfort doing science related research and in pursuing a career in science as compared to the biology and chemistry classes. This could be due to grade level as earth science tends to be a lower level science class, biology medium level and chemistry is an upper level class. Students at lower levels will likely have less experience in reading, writing and researching science related concepts. The trend that I noticed was that higher level classes had more positively changed responses after the treatment.

The student presentations revealed that all of the students were able to perform the necessary reading and research that was assigned to them. One hundred percent were able to differentiate between the fictional science and true science, link themes from their book to current content in class, and were able to compare historical, current and future research potential. This data indicates that the students were becoming more science literate according to the National Science Education Standards. As restated below,

Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy

implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately (National Science Education Standards, p 22).

student presentations indicate they are able to perform science related research, make predictions about future research, discuss the validity and ethics of the research, and were able to present the information to their peers in a formal, unbiased manner with the exception of the opinion portion.

Some students indicated that they were overwhelmed by the amount of reading on top of current content requirements. In the future I would break the reading into smaller components and allow more time. This would help to alleviate the students from being overwhelmed and also to incorporate more pieces of science fiction into specific lesson plans. Some of the book choices such as *Frankenstein* were viewed as too outdated from the students' perception so they often complained of being bored. However, after sharing Mary Shelley's personal story with them, they became more engaged. Chemistry related science fiction pieces were difficult to find, so options were limited in this area. I think more variety of related science fiction would have an even greater impact.

Overall, it seems as though it was a positive experience for most of the students. They were engaged, reading, writing and researching about various types of science. I recall the students reporting to me verbally something they learned from their research that was new and interesting to them. In each of my three classes I have at least two

students that are considered learning disabled, especially with regards to reading and comprehension. A few of them reported that the reading logs I assigned as part of the reading helped them immensely with understanding concepts and that reading the content in fiction form helped them to grasp content. The data indicates that utilizing science fiction to help teach science related concepts has had a positive effect on my students' achievement. The idea currently is that education is "a mile wide and an inch deep" (Nelson, 1999) and the emphasis is to develop better teaching strategies to get our students a more in depth understanding of concepts. During this process I witnessed the students obtaining in depth knowledge about particular areas of science during their research phase. This along with the data, indicate that using science fiction as a science literacy strategy has valuable potential.

VALUE

Through this process I discovered many things about my students and myself as their educator. One thing I'm grateful for was the opportunity to provide my students with an engaging form of science related material that revealed to be much more than that. My students fully cooperated and on most days were excited to do more science fiction. As a reward for their efforts we enjoyed watching a few of the movies based on the books they read which had a surprising outcome. They remarked that the graphics were cool but the story lines had been altered greatly as compared to the book and they were disappointed.

Student feedback during the interview process was invaluable to me and to them as well. They enjoyed giving their input on their learning and wanted their voices heard. This was an opportunity to reflect on my teaching skills and on continuing to create new

ways to keep students engaged. When students are included in their education development, they tend to be more engaged and responsible for their achievement. This was what an unexpected, yet important piece of this project.

Overall, I feel that doing action research is a vital part of education. The process of implementing a new strategy or instrument to use in the classroom is good practice for educators. However, often times we may think something is working, but without the data collection and analysis portion, this may not be true. One thing I had difficulty doing during this process was finding actual research with any quantitative or qualitative data to support the use of science fiction. I found several pieces of reflection that indicated the author “felt” it had a positive impact, but no actual evidence. Although I was optimistic about the strategy being useful, I was concerned it may not be the case. I am quite pleased with this outcome of this action research, not only because it did yield positive results but also to obtain experience with implementing new strategies. The capstone process allowed me to grow as an educator and to develop new skills of my own. The skills I learned in this journey will allow me to continue to listen to my students’ needs and accommodations, get them more involved in their personal achievement, reflect upon my teaching strategies, and finally to go much deeper than “a mile wide and an inch deep” (Nelson, 1999)

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APPENDICES

APPENDIX A
SCIENCE ATTITUDINAL SURVEY

The following survey is designed to assess how you feel about science, reading science related text, and your comfort level with science concepts. Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at any time. Your participation or non-participation will not affect your grade or class standing. Your answers will be kept confidential.

Circle your answer to the questions based on the following scale:

0- not at all

1- rarely

2- occasionally

3- most of the time

- | | | | | |
|---|---|---|---|---|
| 1. I enjoy reading. | 0 | 1 | 2 | 3 |
| 2. I think reading about science is boring. | 0 | 1 | 2 | 3 |
| 3. It is easy for me to read science related text. | 0 | 1 | 2 | 3 |
| 4. It is difficult for me to understand science related text. | 0 | 1 | 2 | 3 |
| 5. I can easily apply what I read to my class work. | 0 | 1 | 2 | 3 |
| 6. It is difficult for me to write about what I learn in science. | 0 | 1 | 2 | 3 |
| 7. I can analyze science related material to find the important concepts. | 0 | 1 | 2 | 3 |
| 8. I am <u>not</u> comfortable doing science related research. | 0 | 1 | 2 | 3 |
| 9. Skills and information I learn in science will be useful to my future. | 0 | 1 | 2 | 3 |
| 10. I am interested in pursuing a career in a science related field. | 0 | 1 | 2 | 3 |

APPENDIX B
STUDENT INTERVIEW QUESTIONS

The following interview is designed to assess how you feel about science, reading science related text, and your comfort level with science concepts. In particular I want to know how you felt about the science fiction portion of the semester. Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at any time. Your participation or non-participation will not affect your grade or class standing. Your answers will be kept confidential.

1. Did the incorporation of science fiction material in our class:

- make reading more fun or interesting?
- help you understand science terminology?
- increase your abilities and or achievement in this class? Can you describe how or in what ways?
- help you to learn concepts expected to learn in class?
- can you provide a specific example of how you made a connection between the science fiction you read and the science topics we are learning about?

2. Were you able to relate science fiction concepts to current science research? Explain.

3. Do you think there is a link between science fiction and current and/or future science? Explain.

4. Did the science fiction component to our class increase your interest in science? Reading or writing in science? Career in science?

5. Do you think that using science fiction was a productive use of time? Why or why not?

6. Overall, how did you feel about reading science fiction in our class?

APPENDIX C

A SAMPLE OF SCIENCE FICTION MATERIAL USED



Underneath were more signs:

**CAUTION
TERATOGENIC SUBSTANCES
PREGNANT WOMEN AVOID EXPOSURE
TO THIS AREA**

**DANGER
RADIOACTIVE ISOTOPES IN USE
CARCINOGENIC POTENTIAL**

Tim grew more excited all the time. Teratogenic substances! Things that made monsters! It gave him a thrill, and he was disappointed to hear Ed Regis say, “Never mind the signs, they’re just up for legal reasons. I can assure you everything is perfectly safe.” He led them through the door. There was a guard on the other side. Ed Regis turned to the group.

“You may have noticed that we have a minimum of personnel on the island. We can run this resort with a total of twenty people. Of course, we’ll have more when we have guests here, but at the moment there’s only twenty. Here’s our control room. The entire park is controlled from here.”

They paused before windows and peered into a darkened room that looked like a small version of Mission Control. There was a vertical glass see-through map of the park, and facing it a bank of glowing computer consoles. Some of the screens displayed data, but most of them showed video images from around the park. There were just two people inside, standing and talking.

“The man on the left is our chief engineer, John Arnold”—Regis pointed to a thin man in a button-down short-



sleeve shirt and tie, smoking a cigarette—"and next to him, our park warden, Mr. Robert Muldoon, the famous white hunter from Nairobi." Muldoon was a burly man in khaki, sunglasses dangling from his shirt pocket. He glanced out at the group, gave a brief nod, and turned back to the computer screens. "I'm sure you want to see this room," Ed Regis said, "but first, let's see how we obtain dinosaur DNA."

The sign on the door said EXTRACTIONS and, like all the doors in the laboratory building, it opened with a security card. Ed Regis slipped the card in the slot; the light blinked; and the door opened.

Inside, Tim saw a small room bathed in green light. Four technicians in lab coats were peering into double-barreled stereo microscopes, or looking at images on high resolution video screens. The room was filled with yellow stones. The stones were in glass shelves; in cardboard boxes; in large pull-out trays. Each stone was tagged and numbered in black ink.

Regis introduced Henry Wu, a slender man in his thirties. "Dr. Wu is our chief geneticist. I'll let him explain what we do here."

Henry Wu smiled. "At least I'll try," he said. "Genetics is a bit complicated. But you're probably wondering where our dinosaur DNA comes from."

"It crossed my mind," Grant said.

"As a matter of fact," Wu said, "there are two possible sources. Using the Loy antibody extraction technique, we can sometimes get DNA directly from dinosaur bones."

"What kind of a yield?" Grant asked.

"Well, most soluble protein is leached out during fossilization, but twenty percent of the proteins are still recoverable by grinding up the bones and using Loy's procedure. Dr. Loy himself has used it to obtain proteins from extinct Australian marsupials, as well as blood cells from ancient human remains. His technique is so





refined it can work with a mere fifty nanograms of material. That's fifty-billionths of a gram."

"And you've adapted his technique here?" Grant asked.

"Only as a backup," Wu said. "As you can imagine, a twenty percent yield is insufficient for our work. We need the entire dinosaur DNA strand in order to clone. And we get it here." He held up one of the yellow stones. "From amber—the fossilized resin of prehistoric tree sap."

Grant looked at Ellie, then at Malcolm.

"That's really quite clever," Malcolm said, nodding.

"I still don't understand," Grant admitted.

"Tree sap," Wu explained, "often flows over insects and traps them. The insects are then perfectly preserved within the fossil. One finds all kinds of insects in amber—including biting insects that have sucked blood from larger animals."

"Sucked the blood," Grant repeated. His mouth fell open. "You mean sucked the blood of dinosaurs ..."

"Hopefully, yes."

"And then the insects are preserved in amber...." Grant shook his head. "I'll be damned—that just might work."

"I assure you, it *does* work," Wu said. He moved to one of the microscopes, where a technician positioned a piece of amber containing a fly under the microscope. On the video monitor, they watched as he inserted a long needle through the amber, into the thorax of the prehistoric fly.

"If this insect has any foreign blood cells, we may be able to extract them, and obtain paleo-DNA, the DNA of an extinct creature. We won't know for sure, of course, until we extract whatever is in there, replicate it, and test it. That is what we have been doing for five years now. It has been a long, slow process—but it has paid off.

"Actually, dinosaur DNA is somewhat easier to extract by this process than mammalian DNA. The reason is that mammalian red cells have no nuclei, and thus no DNA in their red cells. To clone a mammal, you must find a





white cell, which is much rarer than red cells. But dinosaurs had nucleated red cells, as do modern birds. It is one of the many indications we have that dinosaurs aren't really reptiles at all. They are big leathery birds."

Tim saw that Dr. Grant still looked skeptical, and Dennis Nedry, the messy fat man, appeared completely uninterested, as if he knew it all already. Nedry kept looking impatiently toward the next room.

"I see Mr. Nedry has spotted the next phase of our work," Wu said. "How we identify the DNA we have extracted. For that, we use powerful computers."

They went through sliding doors into a chilled room. There was a loud humming sound. Two six-foot-tall round towers stood in the center of the room, and along the walls were rows of waist-high stainless-steel boxes. "This is our high-tech laundromat," Dr. Wu said. "The boxes along the walls are all Hamachi-Hood automated gene sequencers. They are being run, at very high speed, by the Cray XMP supercomputers, which are the towers in the center of the room. In essence, you are standing in the middle of an incredibly powerful genetics factory."

There were several monitors, all running so fast it was hard to see what they were showing. Wu pushed a button and slowed one image.



JURASSIC PARK: A NOVEL



```

1 GGGTGGTGG GGTTTTCCA TAGGTCGCG CCCGTCGAG AGCTGCGAA AATCGAGCG
61 GGTGGCGAA CCCGCGAGA CTATAGAGT ACCGAGCGTT TCGCCGTGA AGCTCCCTG
121 TGTTCGACC CTGCGGCTTA CGGATAGCT GTGCGCTTT CTGCTTCGG GAGGCTGGC
181 TGCTGCGCT GTAGGTATCT CAGTTCGAG TAGGTCGTT GCTCGAGCT GGGCTGTGT
241 CGATTGAGC CGAGCGTGC GCTTATCGG GTAGCTATCG TCTTGATCC AGCCCGTAA
301 AGTAGAGAG GTGCGGAGG CGCTCTGGT GATTTTCGCG GAGGAGCGT TTGCTGAGG
361 ATGCGCTGT CGCTCGGAT ATTGAGATC TTGCGAGCGT TGCTGAGG CTTCGTGCT
421 CGAGCGTTT CGGCGAGAG CGAGCGATTA TCGCGCGAT GCGGCGGAG GCGTGGGCT
481 GCGTTCGCG AGCGAGCT GATGCGCTT CCCGATTAG ATTCTTCTG CTTCGCGCG
541 CGCGCTTGC AGCGAGCT GTGCGGAGG GTAGCTAGC AGGATGAGG AGGCTCGAA
601 CGGCTCTAC CAGCTAGCT TGATGCTG AGCGCTGAT CGTGCAGCG ATTATGCG
661 CGATGAGCG GTTCTGCG GTTTTTCAT AGGCTCGCG CCCGTCGAG GATGCGAA
721 CAGTCTAGG GTGCGAGC CGAGAGAG CTATAGATA CAGGCGTTT CCGCTGAA
781 GCGCTCTCT GTTCGAGCG TGCGGCTAC CGATGCTG TCGGCTTTC TCGCTCGG
841 CTTCGTAT GCTCAGCTG TAGGTATCT AGTGGGTGT AGGCTGTTG CTGAGCTG
901 AGAGCGCG GAGCGAGCG AGCTGAGCT GATGAGAG CGGCGAGCG TGCTGAGG
961 AGGAGCTTA AGGAGTGG ATGATTTGA GAGCGCGCG TATAGCTGT CTGCTCGCG
1021 GCGTGTGAG GAGCGAGCG AGCTGAGCT GATGAGAG CGGCGAGCG TGCTGAGG
1081 CGAGGATTT GAGCGATC ATTCTGCG AGGCTGAT ATGCGAGAG CAGGCTTGG
1141 CGATGAGCT CAGCTCTCG AGAGCGCG CAGCGAGCT CTGCGAGCG GTTGTGCT
1201 GCGATGAT GTCT - - - CCGTGTGTT AGAGCGCG TAGGTCGCG GGTTCGCT
1261 AGATGATC ACCGATGCG AGGAGGCT GAGGAGCT CTGCTGAA AGCTCTGCA
1341 AGATGATG GTCTGCTT TCGTGTTC GTAGGCTG GAGGCGAG AGTACGCG

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“Here you see the actual structure of a small fragment of dinosaur DNA,” Wu said. “Notice the sequence is made up of four basic compounds—adenine, thymine, guanine, and cytosine. This amount of DNA probably contains instructions to make a single protein—say, a hormone or an enzyme. The full DNA molecule contains *three billion* of these bases. If we looked at a screen like this once a second, for eight hours a day, it’d still take more than two years to look at the entire DNA strand. It’s that big.”

He pointed to the image. “This is a typical example, because you see the DNA has an error, down here in line 1201. Much of the DNA we extract is fragmented or incomplete. So the first thing we have to do is repair it—or rather, the computer has to. It’ll cut the DNA, using what are called restriction enzymes. The computer will select a variety of enzymes that might do the job.”

1 CGGTGCTGGCGTCTTTTCCTAGAGCTCCGCCCCCTGACGACGATACACAAATTCAGCG
61 GTGTGGCAACCCGACAGCATTAAGATACACAGCGCTTTCCCTCTGGAGCTCCCTCG
Nsp4
121 TGTCTGCAGCCCTGGCCGCTTACCGATGTCTGTCCGCTTTCTCTCTGGAGAGAGTGTC
181 TGCTGCATGCTAAGTATGTCTGCTGATGCTAGTCTTCCGTCGAGGCTGGCTGTGCTG
α Brn117
241 CGCTTCAGCCGCGACCGCTCGGCTCTAGCTGCTACGTATCGCTTGATTCACCGCGTTAT
301 AGTAGAGAGCTGCGCGACGACGCTTGCGTATTTTTCGCGACAGGCCCTTTCTGCTGGAG
434 DnT1 αBh
361 ATCGGCTCTGCTCGGATCTCGGATATCTGCACGATCTGCACGACCTCGTACAGCTGTGCTAT
421 CCACAGCTCTGCAGCAGAGGACGACGCTGCTCCGCGAGTGGCGGACGCGCGCTGGCT
481 GGCTCTTCGACACGACGAGCTGGATGGCTTCCCATTTATGATCTTCTGCTTCGCGCG
541 CCGCGCTTCGACGACGATCTGCTCCAGGAGGTGATGACGACATCAGAGAGAGCTATTC
601 CGCTCTTACGCGTCTACTCTGCTTACGTCGCGCTGCTGCGATCGATATTTACCG
Nsp4
661 CAGTGGACGCTGTTCTGGCGTTTTCCTAGAGCTCCGCCCCCTGACGACGATACACAA
721 CAGCTCAGGTGCTGGCGAACCCGACGACGATTAAGATACACAGCGCTTTCCCTCTGGAG
924 Caell1 Dnln4
781 CGGCTCTCTGCTCGACGCTCGGCTCTACCGCATGTCTCGGCTTCTCTCTCTCGG
841 CTTTCATGATCTGACGCTGTGATGATATCTGATCTGGGTGTAGTGGCTGCTCGCTCCTAG
901 ACACACCGCCGCTTTCGCGCGACGCTCGGCTCTATCCGCGATCATCTGCTGTAGTGC
961 AGACGCTCTTAGCGGTCTTGATGGATGTATAGGCGCGACCTACTCTTGTGCTCGCT
1021 GCGTGTGATGGACGCGGACGCTCTGACCTGATGACGAGCGCGGACGACCTGCTTAGCG
1081 CCAGATGTTGGAGCCATCATCTATCTTCGCGAGACTGTGATGCGCAACCAACCTCTG
1141 CACTGCTGCTCCGACTCTCCGACGCGGACGCGCGCTGCTTCCGACGATCTGGGCTCT
1416 DnT1
1201 GCGCATGCTGCTCTTCTCGCTCTTGACGACCGGCTAGGCTCGCGGGGCTCTCTAGCT
1261 ATGATCATGATCATGCGACGCGACGCTGTAGGACGCTCTGCTGCACAAATCTGCGACCT
1321

“Here is the same section of DNA, with the points of the restriction enzymes located. As you can see in line 1201, two enzymes will cut on either side of the damaged point. Ordinarily we let the computers decide which to use. But we also need to know what base pairs we should insert to repair the injury. For that, we have to align various cut fragments, like so.”

Thiotimoline To The Stars, Isaac Asimov

"Same speech, I suppose," said Ensign Feet wearily.

"Why not?" said Lieutenant Frohorov, closing his eyes and carefully sitting down on the small of his back. "He's given it for fifteen years, once to each graduating class of the Astronautic Academy."

"Word for word, I'll bet," said Feet, who had heard it the year before for the first time.

"As far as I can tell. -What a pompous bore! Oh, for a pin that would puncture pretension."

But the class was filing in now, uniformed and expectant, marching forward, breaking into rows with precision, each man and woman moving to his or her assigned seat to the rhythm of a subdued drumbeat, and then all sitting down to one loud boom.

At that moment Admiral Vernon entered and walked stiffly to the podium.

"Graduating class of '22, welcome! Your school days are over. Your education will now begin.

"You have learned all there is to know about the classic theory of space flight. You have been filled to overflowing with astrophysics and celestial relativistic mechanics. But you have not been told about thiotimoline.

"That's for a very good reason. Telling you about it in class will do you no good. You will have to learn to *fly* with thiotimoline. It is thiotimoline and that alone that will take you to the stars. With all your book learning, you may still never learn to handle thiotimoline. If so, there will yet be many posts you can fill in the astronautic way of life. Being a pilot will not, however, be one of them.

"I will start you off on this, your graduation day, with the only lecture you will get on the subject. After this, your dealings with thiotimoline will be in flight and we will find out quickly whether you have any talent for it at all."

The admiral paused, and seemed to be looking from face to face as though he was trying to assay each man's talent to begin with. Then he barked:

"Thiotimoline! First mentioned in 1948, according to legend, by Azimuth or, possibly, Asymptote, who may, very likely, never have existed. There is no record of the original article supposed to have been written by him; merely vague references to it, none earlier than the twenty-first century.

"Serious study began with Almirante, who either discovered thiotimoline, or rediscovered it, if the Azimuth/Asymptote tale is accepted. Almirante worked out the theory of hyperstercic hindrance and showed that the molecule of thiotimoline is so distorted that one bond is forced into extension through the temporal dimension into the past; and another into the future.

"Because of the future-extension, thiotimoline can interact with an event that has not yet taken place. It can, for instance, to use the classic example, dissolve in water approximately one second before the water is added.

"Thiotimoline is, of course, a very simple compound, comparatively. It has, indeed, the simplest molecule capable of displaying endochronic properties-that is, the past-future extension. While this makes possible certain unique devices, the true applications of endochronicity had to await the development of more complicated molecules; polymers that combined endochronicity with firm structure.

“Pellagrini was the first to form endochronic resins and plastics, and, twenty years later, Cudahy demonstrated the technique for binding endochronic plastics to metal. It became possible to make large objects endochronic-entire spaceships, for instance.

“Now let us consider what happens when a large structure is endochronic. I will describe it qualitatively only; it is all that is necessary. The theoreticians have it all worked out mathematically, but I have never known a physics-johnny yet who could pilot a starship. Let them handle the theory, then, and you handle the ship.

“The small thiotimoline molecule is extraordinarily sensitive to the probabilistic states of the future. If you are certain you are going to add the water, it will dissolve before the water is added. If there is even the slightest doubt in your mind as to whether you will add the water, the thiotimoline will not dissolve until you actually add it.

“The larger the molecule possessing endochronicity, the less sensitive it is to the presence of doubt. It will dissolve, swell, change its electrical properties, or in some way interact with water, even if you are almost certain you may not add the water. But then what if you don't, in actual fact, add the water? The answer is simple. The endochronic structure will move into the future in search of water; not finding it, it will continue to move into the future.

“The effect is very much that of the donkey following the carrot fixed to a stick and held two feet in front of the donkey's nose; except that the endochronic structure is not as smart as the donkey, and never gets tired.

“If an entire ship is endochronic-that is, if endochronic groupings are fixed to the hull at frequent intervals-it is easy to set up a device that will deliver water to key spots in the structure, and yet so arrange that device that although it is always apparently on the point of delivering the water, it never actually does.

“In that case, the endochronic groupings move forward in time, carrying all the ship with it and all the objects on board the ship, including its personnel.

“Of course, there are no absolutes. The ship is moving forward in time relative to the universe; and this is precisely the same as saying that the universe is moving backward in time relative to the ship. The rate at which the ship is moving forward, or the universe is moving backward, in time, can be adjusted with great delicacy by the necessary modification of the device for adding water. The proper way of doing this can be taught, after a fashion; but it can be applied perfectly only by inborn talent. That is what we will find out about you all; whether you have that talent.”

Again he paused and appraised them. Then he went on, amid perfect silence:

“But what good is it all? Let's consider starflights and review some of the things you have learned in school.

“Stars are incredibly far apart and to travel from one to another, considering the light-speed limit on velocity, takes years; centuries; millennia. One way of doing it is to set up a huge ship with a closed ecology; a tiny, self-contained universe. A group of people will set out and the tenth generation thereafter reaches a distant star. No one man makes the journey, and even if the ship eventually returns home, many centuries may have passed.

“To take the original crew to the stars in their own lifetime, freezing techniques may keep them in suspended animation for virtually all the trip. But freezing is a very uncertain procedure, and even if the crew survives and returns home, they will find that many centuries have passed on Earth.

“To take the original crew to the stars in their own lifetime, without freezing them, it is only necessary to accelerate to near-light velocities. Subjective time slows, and it will seem to the crew that it will have taken them only months to make the trip. But time travels at the normal rate for the rest of the universe, and when the crew returns they will find that although they, themselves, have aged and experienced no more than two months of time, perhaps, the Earth itself will have experienced many centuries.

“In every case, star travel involves enormous duration of time on Earth, even if not to the crew. One must return to Earth, if one returns at all, far into the Earth's future, and this means interstellar travel is not psychologically practical.

“But- *But*, graduates-”

He peered piercingly at them and said in a low, tense voice, “*If* we use an endochronic ship, we can match the time-dilatation effect exactly with the endochronic effect. While the ship travels through space at enormous velocity, and experiences a large slowdown in rate of experienced time, the endochronic effect is moving the universe back in time with respect to the ship. Properly handled, when the ship returns to Earth, with the crew having experienced, say, only two months of duration, the entire universe will have likewise experienced only two months' duration. At last, interstellar travel became practical.

“But only if very delicately handled.

“If the endochronic effect lags a little behind the time-dilatation effect, the ship will return after two months to find an Earth four months older. This is not much, perhaps; it can be lived with, you might think; but not so. The crew members are out of phase. They feel everything about them to have aged two months with respect to themselves. Worse yet, the general population feels that the crew members are two months younger than they ought to be. It creates hard feelings and discomforts.

“Similarly, if the endochronic effect races a little ahead of the time-dilatation effect, the ship may return after two months to find an Earth that has not experienced any time duration at all. The ship returns, just as it is rising into the sky. The hard feelings and discomforts will still exist.

“No, graduates, no interstellar flight will be considered successful in this star fleet unless the duration to the crew and the duration to Earth match minute for minute. A sixty-second deviation is a sloppy job that will gain you no merit. A hundred-twenty-second deviation will not be tolerated.

“I know, graduates, very well what questions are going through your minds. They went through mine when I graduated. Do we not in the endochronic ship have the equivalent of a time machine? Can we not, by proper adjustment of our endochronic device, deliberately travel a century into the future, make our observations, then travel a century into the past to return to our starting point? Or vice versa, can we not travel a century into the past and then back into the future to the starting point? Or a thousand years, or a billion? Could we not witness the Earth being born, life evolving, the sun dying?

“Graduates, the mathematical-johnnies tell us that this sort of thing creates paradoxes and requires too much energy to be practical. But I tell you the hen with paradoxes. We can't do it for a very simple reason. The endochronic properties are unstable. Molecules that are puckered into the time dimension are sensitive indeed. Relatively small effects will

cause them to undergo chemical changes that will allow unpuckering. Even if there are no effects at all, random vibrations will produce the changes that will unpucker them.

“In short, an endochronic ship will slowly go isochronic and become ordinary matter without temporal extension. Modern technology has reduced the rate of unpuckering enormously and may reduce it further still, but nothing we do, theory tells us, will ever create a truly stable endochronic molecule.

“This means that your starship has only a limited life as a starship. It must get back to Earth while its endochronicity still holds, and that endochronicity must be restored before the next trip.

“Now, then, what happens if you return out-of-time? If you are not very nearly in your own time, you will have no assurance that the state of the technology will be such as to enable you to re-endochronicize your ship. You may be lucky if you are in the future; you will certainly be unlucky in the past. *If*, through carelessness on your part, or simply through lack of talent, you come back a substantial distance into the past, you will be certain to be stuck there because there will be no way of treating your ship in such a fashion as to bring it back into what will then be your future.

“And I want you to understand, graduates,” here he slapped one hand against the other, as though to emphasize his words, “there is no time in the past where a civilized astronaut officer would care to spend his life. You might, for instance, be stranded in sixth-century France or, worse still, twentieth-century America.

“Refrain, then, from any temptation to experiment with time.

“Let us now pass on to one more point which may not have been more than hinted at in your formal school days, but which is something you will be experiencing.

“You may wonder how it is that a relatively few endochronic atomic bonds placed here and there among matter which is overwhelmingly isochronic can drag an with it. Why should one endochronic bond, racing toward water, drag with it a quadrillion atoms with isochronic, bonds? We feel this should not happen, because of our lifelong experience with inertia.

“There is, however, no inertia in the movement toward past or future. If one part of an object moves toward the past or future, the rest of the object does so as well, and at precisely the same speed. There is no mass-factor at all. That is why it is as easy for the entire universe to move backward in time as for this single ship to move forward-and at the same rate.

“But there is even more to it than that. The time-dilatation effect is the result of your acceleration with respect to the universe generally. You learned that in grade school, when you took up elementary relativistic physics. It is part of the inertial effect of acceleration.

“But by using the endochronic effect, we wipe out the time-dilatation effect. If we wipe out the time-dilatation effect, then we are, so to speak, wiping out that which produces it. In short, when the endochronic effect exactly balances the time-dilatation effect, the inertial effect of acceleration is canceled out.

“You cannot cancel out one inertial effect without canceling them all. Inertia is therefore wiped out altogether and you can accelerate at any rate without feeling it. Once the endochronic effect is well-adjusted, you can accelerate from rest relative to Earth, to 186,000 miles per second relative to Earth in anywhere from a few hours to a few

minutes. The more talented and skillful you are at handling the endochronic effect, the more rapidly you can accelerate.

"You are experiencing that now, gentlemen. It seems to you that you are sitting in an auditorium on the surface of the planet Earth, and I'm sure that none of you has had any reason or occasion to doubt the truth of that impression. But it's wrong just the same.

"You are in an auditorium, I admit, but it is not on the surface of the planet, Earth; not anymore. You-I-all of us-are in a large starship, which took off the moment I began this speech and which accelerated at an enormous rate. We reached the outskirts of the solar system while I've been talking, and we are now returning.

"At no time have any of you felt any acceleration, either through change in speed, change in direction of travel, or both, and therefore you have all assumed that you have remained at rest with respect to the surface of the Earth.

"Not at all, graduates. You have been out in space all the time I was talking, and have passed, according to calculations, within two million miles of the planet Saturn."

He seemed grimly pleased at the distinct stir in the audience.

"You needn't worry, graduates. Since we experience no inertial effects, we experience no gravitational effects either (the two are essentially the same), so that our course has not been affected by Saturn. We will be back on Earth's surface any moment now. As a special treat we will be coming down in the United Nations Port in Lincoln, Nebraska, and you will all be free to enjoy the pleasures of the metropolis for the weekend.

"Incidentally, the mere fact that we have experienced no inertial effects at all shows how well the endochronic effect matched the time-dilatation. Had there been any mismatch, even a small one, you would have felt the effects of acceleration-another reason for making no effort to experiment with time.

"Remember, graduates, a sixty-second mismatch is sloppy and a hundred-twenty-second mismatch is intolerable. We are about to land now; Lieutenant Prohorov, will you take over in the conning tower and oversee the actual landing?"

Prohorov said briskly, "Yes, sir," and went up the ladder in the rear of the assembly hall, where he had been sitting.

Admiral Vernon smiled. "You will all keep your seats. We are exactly on course. My ships are always exactly on course."

But then Prohorov descended again and came running up the aisle to the admiral. He reached him and spoke in a whisper. "Admiral, if this is Lincoln, Nebraska, something is wrong. All I can see are Indians; hordes of Indians. Indians in Nebraska, *now*, Admiral?"

Admiral Vernon turned pale and made a rattling sound in his throat. He crumpled and collapsed, while the graduating class rose to its feet uncertainly. Ensign Peet had followed Prohorov onto the platform and had caught his words and now stood there thunderstruck.

Prohorov raised his arms. "All's well, ladies and gentlemen. Take it easy. The admiral has just had a momentary attack of vertigo. It happens on landing, sometimes, to older men."

Peet whispered harshly, "But we're stuck in the past, Prohorov."

Prohorov raised his eyebrows. "Of course not. You didn't feel any inertial effects, did you? We can't even be an hour off. If the admiral had any brains to go with his uniform, he would have realized it, too. He had just *said* it, for God's sake."

"Then why did you say there was something wrong? Why did you say there are Indians out there?"

“Because there was and there are. When Admiral Sap comes to, he won't be able to do a thing to me. We didn't land in Lincoln, Nebraska, so there was something wrong all right. And as for the Indians-well, if I read the traffic signs correctly, we've come down on the outskirts of Calcutta.”

APPENDIX D

GROUP QUESTIONS AND WRITING PROMPTS

Jurassic Park

In groups of no more than three, discuss the questions below and write your responses using complete sentences where applicable (additional paper may be necessary). A portion of this assignment will need to be done in the computer lab using internet sources. Remember what valid sources are as compared to sites such as Wikipedia that isn't always accurate.

Briefly describe the plot, setting and characters of this section of Jurassic Park.

What technology, if any, is being used in this section?

Are there any words you don't understand? Use the dictionary to define them.

Is there anything in this section that doesn't make sense?

What type of science is being conveyed? Anything you've ever heard of before? If so, what do you already know?

Computer Lab Questions

How long can DNA remain undegraded in amber? What does undegraded mean?

How many fossil sites exist and how old are they?

How rare are amber-trapped mosquitos?

How do you separate dinosaur DNA from other DNA in the mosquito gut?

What portion of the dinosaurs' 160 million years history could you successfully sample?

How can you know which parts and how much of the dinosaur genome is missing and what to replace them with?

What's involved in creating embryos from somatic cells (cloning)?

This book should have been named Cretaceous Park rather than Jurassic Park? Why?

Writing Assignment

Now that you've discussed and researched the science themes involved in this section of Jurassic Park, it's time to evaluate the logistics. Based on what you now know about DNA cloning, extraction, amber trapped mosquitos etc. explain what parts are accurate or possible and which parts are just fiction. Make sure to give specific evidence to support your claims.

A portion of this assignment was adapted from Teaching Science Fact with Science Fiction by Gary Raham, 2004.

Thiotimeline by Isaac Asimov Part 1

What is meant by flying with Thiotimeline?

What is Thiotimeline?

What/who are Azimuth and Asymptote? Have you ever heard these terms before? If so, in what aspect?

Who is Almirante?

What do you think is meant by hypersterc hindrance? Then, look it up and compare your answer.

What do you think is meant by future-extension?

What are endochronic propoerties?

What is a polymer?

What are probabilistic states? Can you think of anything we are studying in class that might fit into a probabilistic state?

Based on the last paragraph what do you think will happen to the structure or the environment during the time it takes to find the water it's searching for?

Briefly summarize your understanding of the story so far.

Thiotimoline, Asimov Part 2

Compare endochronic structures to the equilibrium of chemical reactions

What do you think “fixed to the hull” means? Then, look it up and compare your answer.

How does the ship move forward?

What do you think about this- the ship moves forward in time relative to the universe is the same as the universe is moving backward in time relative to the ship? Explain your thought and try to come up with an example of how this applies in chemistry.

Why is the speed of light a limiting factor to consider?

Why does it seem as only two months have passed to the crew, but the Earth has been through several centuries?

How can this effect be overcome? Explain and define the terms being used in the paragraph where this information can be found.

Can you think of any potential issues that could arise from the possible solution?

What are your thoughts on the last sentence about the ship being equivalent of a time machine?

Thiotimeline, Asimov Part 3

What do you think is meant by the term mathematical Johnnies?

What is a paradox?

What is meant by saying that the molecules are puckered? What are the effects that unpucker them? Be sure to explain what this means.

What is meant by isochronic?

What is a temporal extension?

According to the story, when/where is the worst time to be stuck?

Explain paragraph number 5 with regards to chemical bonding.

What is inertia? Why is it an issue?

What is the time-dilatation effect? How is it “wiped out”?

The last paragraph indicates that the students were on this ship and traveling without being aware. Wouldn't you be aware of it somehow? Explain why or why not.

Thiotimoline by Isaac Asimov Part 4

If you're within 2 million miles of Saturn, how far have you travelled?

Explain how there can be no inertial or gravitational effects.

The story discusses that a 60 second mismatch would be sloppy and a 120 second mismatch would be intolerable. What are they referring to? Why is this so strict? How does this apply to some chemical reactions?

APPENDIX E
READING GUIDE AND CONCEPT LOG

Reading and Concept Log

Answer the following in your science journal using complete sentences. As you read your book you may not need to answer questions 3-7 unless it changes.

Title:

Author:

Publication Date:

1. I read pages _____ through _____
2. List any words that are unfamiliar to you and then define them prior to additional reading.
3. What is the setting of this book?(ie time and place)
4. Who are the characters of the book and what role do they play? (this may change as you read)
5. Can you identify any science themes related to anything we are currently learning in class?
6. Can you identify any science or technology related themes that are already familiar to you?
7. Write a few sentences describing anything that is confusing or doesn't make sense. Be sure to explain why.
8. Using a few sentences describe what's going on in the plot thus far.
9. Can you predict where the story might go? What information in the story makes you think that might happen? Use concrete examples from the book.
10. Were there things that you didn't understand prior to the reading that you now understand? Be specific

APPENDIX F
RESEARCH GUIDELINES

Science Presentation Rubric

Your objective is to develop a powerpoint or prezi presentation about the book you read. You must present this to the class. You need to provide a works cited page and YOU WILL NOT USE WIKIPEDIA! You will be graded on the following criteria.

1. Give background of your author. _____/5
 2. Inclusion of reading log entries: _____/5
 - Vocabulary
 - Process of the changing themes
 3. Process of the changes in setting, characters etc. _____/10
 - What was science like at the time the book was written?
 - Newest technology
 - Latest scientific discoveries
 - Controversies of science at that time
 4. What science themes emerge throughout the book? _____/5
 5. What are the differences in technology and science since the time the book was written until today? _____/15
 - Give examples of how each has developed: who discovered / invented it, who enhanced it, etc.
 6. What science theme/s from your book are just fiction, no true science to back it up? _____/5
 7. What themes are currently being researched for its potential? Give examples! _____/10
 8. What theme/s do suspect may be possible in the future. Explain. _____/5
 9. State your opinion (back it up) _____/10
 - Did this book help you understand science related themes?
 - Was this engaging reading material?
 - Does this type of reading promote your interest in science?
 10. Overall presentation _____/30
 - Prepared and Organized
 - Powerpoint/Prezi is formatted well (color, font, organization, pictures etc.)
 - References Cited
- Total _____/100