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A STE[A]M Approach to Teaching and Learning

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Since the advent of STEM (Science, Technology, Engineering and Math) programs, first in K-12 and now in college curricula, many variants of STEM have arisen to include other disciplines in developing cross-disciplinary literacy among students. This paper briefly defines our own variant STE[A]M branch within the context of cross-disciplinary teaching and learning and then describes an interdisciplinary course, The Science in Science Fiction, in which professors of Biology, English, and Physics provided a range of science fiction texts which undergraduate and graduate students studied and discussed in depth. Students then produced and presented collaborative cross-disciplinary research on topics of their choice from the course work. Finally, students provided input on their experiences with collaborative cross-disciplinary teaching and learning. The overall effect was extremely positive. This article provides a framework for other faculty who would like to model this approach.

According to the United States Government Accountability Office (2005), the current STEM—Science, Technology, Engineering, and Math—Program in the United States began as a K-12 initiative “to collapse the teaching of these subjects individually by using a more interdisciplinary approach to learning, and this was in response to growing concerns that American students were not keeping pace with other students from other countries in these fields” (p. 11). The central aim of the first STEM programs was to “improve teacher quality” by providing educators with an expanded and more integrated knowledge base for their teaching (p. 11), or, in other words, with “cross-disciplinary literacy” (p. 11), which has since become a term within the Common Core (Common Core State Standards Initiative, 2015).

However, since its inception, STEM interest has broadened into post-secondary education as demand for highly skilled graduates has been on the rise (Dugger, 2010), and its offshoots are responses to a growing contemporary awareness that more interplay and integration among disciplines provide more student involvement and interconnected learning, not only for teacher education students, but also for students across fields and levels of education:

> The Committee on STEM Education (CoSTEM), comprised of 13 agencies—including all of the mission-science agencies and the Department of Education—are facilitating a cohesive national strategy, with new and repurposed funds, to increase the impact of federal investments in five areas: 1.) improving STEM instruction in preschool through 12th grade; 2.) increasing and sustaining public and youth engagement with STEM; 3.) improving the STEM experience for undergraduate students; 4.) better serving groups historically underrepresented in STEM fields; and 5.) designing graduate education for tomorrow's STEM workforce. (U.S. Department of Education, 2015)

In conjunction with these aims and to broaden them, American colleges and universities have expanded this approach. Examples include STE[A]M for Science, Technology, Engineering, Art & Design, and Math (RISD Academic Affairs: STEM to STEAM, 2017) and STEAM-H for Science, Technology, Engineering, Agriculture, Math and Health (Virginia State University, 2005). Our particular variant is STE[A]M, Science, Technology, Engineering, the Arts, and Math, in which “the Arts” include literature, film, visual imagery, and other media to provide additional context and critical thought in our science-oriented literature course.

Literature Review

The Critical Interplay of Arts and Sciences

Engaging artistic imagination and scientific interplay is not new, and humans’ centuries-old fascination with flight is a case in point. For example, 2000 years ago the Roman poet Ovid imagined the inventor Daedelus’s crafting and use of artificial wings (Book II: lines 71-95), and other imaginative writers envisioned methods of flight and space exploration centuries before these creative ideas were made real by modern science and technology. As Stephen Hawking (1995) notes in his Forward to Lawrence Krauss’s *The Physics of Star Trek*, “Science fiction […] is not only good fun, but it also serves a serious purpose, that of expanding the human imagination. . . Science fiction suggests ideas that scientists incorporate into their theories . . .” (pp. xi-xii). Indeed, Einstein revealed, "When I examine myself and my methods of thought, I come close to the conclusion that the gift of imagination has meant more to me than any talent for absorbing absolute knowledge" (Calaprice, 2000, p. 22). The versatile Leonardo DaVinci also depended on this kind of interplay:

> Leonardo made the faculty of vision—or more precisely, the gift and patience of intensive observation—the foundation of both his scientific investigations and his work as a figural artist. He was a protoscientist in the modern sense of what constitutes science, bringing to his investigation of the natural world not only an extraordinary artistic imagination, but a unique and idiosyncratic intellectual position that helped him to circumvent the mental blocks of his contemporaries. (Ackerman, 1998, p. 207)

Not only is this interplay not new, it is not unusual. Chemist and Nobel Prize recipient Robert Woodward (2003) asserted that aesthetics provided an essential impetus and insight for his groundbreaking work and then noted the following revelation about his colleagues at Harvard:

> It was many more years, however, before I realized that the kinds of personal aesthetic experiences I had been accumulating were common to other scientists. Many had a visceral, sensual love affair with their experimental and even theoretical work. Concepts of simplicity, symmetry or asymmetry, elegance, and beauty were common . . . Few colleagues spoke publicly about such things. It therefore came as a revelation to discover just how completely aesthetic considerations and experiences permeate chemistry and other sciences, their teaching, learning, and meaning. (pp. 37-38)

However, while these examples illustrate the relevance of art to science and vice versa, and while some scientists make innate connections between aesthetics and scientific study, the skill of knowledge enhancement through such interplay between art and science is perhaps not always innate and, thus, for many requires essential training. Root-Bernstein et al. (2008) assert the importance of an interdisciplinary curriculum that includes the arts as particularly critical for future scientists as well as for society, and they express concern over the effect of a lack of arts education for students of science: “The utility of arts and crafts training for scientists may have important public policy and educational implications in light of the marginalization of these subjects in most curricula” (p. 51).

Indeed, understanding, emphasizing, and utilizing the interplay between science and art will have profound effects for the future for societies on an international scale, and according to Carol Neves (2010), Director of the Smithsonian’s Office of Policy and Analysis, academia must play a role in this future. In the Preface of the Smithsonian Institution’s 2010 report, *Interplay of Perspectives: History, Art & Culture + Science, Interdisciplinary Crossover and Collaboration* she asserts:

> Few would dispute the notion that many of the problems that the world faces today are large and complex. Solving them requires a strong intellectual orientation that draws upon history, art, culture and science. Major universities and a few other institutions have the potential to transcend disciplines, and when they do, much of their interdisciplinary work occurs outside formal channels (p. 1).

In short, a societal need exists for interplay and interconnectedness among arts and sciences which will enhance future leaders’ abilities to effectively solve complex problems. This course and courses like it foster that interconnectedness which ultimately enhances students’ learning and their abilities to contribute to society in meaningful ways.

The Development and Teaching of Science Fiction Courses

While science fiction has existed for millennia, it was not taught as a specialized course on a collegiate level until the mid-twentieth century. Lester Del Rey (1979), science fiction author and documenter of the genre’s growth in America, asserts the following:

> The first college course on science fiction that I can discover was given as a night school course at City College of New York Extension School; this began in 1953 and was conducted by Sam Moskowitz . . . Certainly this was the oldest continuing course on science fiction. At that time, Moskowitz had no difficulty in securing such writers as Heinlein and Asimov as guest lecturers (p. 224).

In *In Memory Yet Green: The Autobiography of Isaac Asimov*, Asimov (1979) supports this assertion: “I drove into New York to oblige Sam Moskowitz who was giving a class in science fiction . . . Sam’s class may have been the first college class in science fiction” (p. 692). Forty-three years later the article “North American College Courses in Science Fiction, Utopian Literature, and Fantasy,” by Arthur Evans (1996), was published in *Science Fiction Studies*, and in it he listed 404 science fiction courses in the U.S. as well as Europe. He also included addenda of the most frequently assigned texts. At the end he notes, “At the heart of science fiction lies a speculative energy" (Evans, 1996). It is this energy that fuels the inherently interdisciplinary science fiction course. However, it has its challenges. As John Woodcock (1979) observes, "Few courses combine such high hopes, on the part of both students and faculty, with such a variety of teaching challenges," and he includes among them students' anxiety regarding disciplines like math, as well as the professors' struggle with "the classic literary question of realism in a way that is meaningful for works that are fantastic, or predictive, or both,"

Despite these challenges, science fiction offers diverse opportunities for learning across disciplines in academia, and one chief reason for this is the versatile nature of the genre itself. As Gunn (1996) notes, science fiction is "inclusive" of other genres from the "detective story" to the "love story" to the "adventure story" (p. 377), and as such it can incorporate academic subjects such as "social and physical sciences, history, ideas, futurology, religion, morality, ecology, reading skills, and many others" (p. 377). McBride (2016) explored the positive effects of linking science fiction and physics courses. Also, in teaching an "interdisciplinary" science fiction course "with an emphasis on ethics of technology and science," Layton (2010) notes that this "helps break student misconceptions that every course is a unique event unrelated to other courses" (15.1341.9). Finally, Pease (2009) observes the following: "Science fiction offers many opportunities to exercise the moral imagination, through attempts to anticipate future technological developments and to explore both the benefits and dangers of these developments. The genre is also fertile with ground for exploring human relationships, treatment of the Self and the Other, as well as environmental issues, just to name a few examples" (p. 75).

Method

The Science in Science Fiction

The science fiction course was developed by professors of Biology, Physics, and English and was open to undergraduate students in English and Biology and graduate students in the Masters of Arts in Teaching Biology, Master of Arts in Teaching English, and the Master of Arts in Liberal Studies. Course participants initially included five English majors and four biology majors, but two students from each major could not complete the course. The class met two evenings a week for one semester.

Active Learning Approaches

The course focused on active learning, a general term for student-centered learning in which the student constructs knowledge by building on hands-on learning experiences rather than absorbing knowledge passively from traditional external sources such as lectures. Active learning includes cooperative and collaborative learning.

The ground-breaking research of Chickering and Gamson (1987) found that active learning is superior to traditional forms of instruction:

> Learning is not a spectator sport. Students do not learn much just by sitting in classes listening to teachers, memorizing prepackaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences and apply it to their daily lives. They must make what they learn part of themselves . . . Active learning is encouraged in classes that use structured exercises, challenging discussions, team projects, and peer critiques. (p. 1)

Drawing upon Chickering and Gamson's seminal research, Bonwell and Eison (1991) assert that "students must do more than just listen. They must read, write, discuss, or be engaged in solving problems. Most important, to be actively involved, students must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation" (p. 1). The authors summarize active learning as use of "instructional activities involving students in doing things and thinking about what they are doing" (Bonwell & Eison, 1991, p. 1). Mayer (2002) refers to active learning as "meaningful learning" which "occurs when students build the knowledge and cognitive processes needed for successful problem solving" (p. 226). Collaborative learning is defined thusly:

> [It] is an umbrella term for a variety of educational approaches involving joint intellectual effort by students, or students and teachers together . . . Collaborative learning activities vary widely, but most center on students' exploration or application of the course material, not simply the teacher's presentation or explication of it." (Smith & MacGregor, 2015).

Cooperative learning has been defined as "a teaching strategy in which small teams, each with students of different levels of ability, use a variety of learning activities to improve their understanding of a subject" (Balkcom, 1992).

Course Organization

Given the diverse disciplines of the students and of the faculty members whose grading systems might vary according to discipline, we had to ensure that the syllabus was thorough and explicit from the outset with a complete schedule of class activities, course texts, course policies, individual and group assignment instructions, and grading rubrics with detailed grade assessment methods for all assignments (see examples at Appendix A). The syllabus was lengthy, but we needed to make sure that we were clearly focused on the course content, on active student-centered learning, and on our expectations from the students as well as ourselves. The texts were selected according to the expertise of faculty members, so in the course there was emphasis on physics, biology, and literary concepts and theory. Texts were listed and studied in chronological order beginning in the eighteenth century and ending in the 21st century so that students could understand the development of science fiction as a genre and recognize the connections among texts and the historical contexts in which they were written.

In addition, from the outset of the course we used Desire2Learn (D2L), an online course delivery system, for practical purposes such as the Dropbox for delivery of assignments, but the greater purpose of D2L was to provide both some course texts and all scientific, literary, and contextual discussion questions each week for students to contemplate while reading the works in order to prepare for that week's class discussions. All three instructors provided questions for each reading. Students were also provided with links to sites both to increase their understanding of a work and to broaden their perspectives beyond the immediate context of the work itself, including beyond the medium in which it was produced. Thus, students were encouraged to use both course texts and additional online resources to prepare themselves for in-class discussions. The links to online sites also aided students' pursuit of their own interests associated with the literature texts, an independent active learning process which we strongly nurtured and encouraged.

Class Activities

The class met two evenings per week, and collaborative learning using various means was woven into the texture of every class session. For a few classes, a professor gave a 10- or 15-minute mini-lecture at the beginning to provide necessary context (e.g., the biologist reviewing a biological concept presented in a reading), but this was the rare exception rather than the rule. Usually, and with faculty members' encouragement, students participated in each lively open class discussion based on question responses in D2L, as well as on additional explorations that students had made beyond D2L.

Students also had regular short explication assignments to aid in the class's understanding of a particular topic in the reading(s). One example among many includes our study of Nathaniel Hawthorne's (1844) 19th century short story, "Rappacini's Daughter," in which a prominent scientist exposes his daughter to poison from birth so that the only mate she could have in life would have to be similarly poisoned and thus immune to her touch: all others would die. As an assignment for this text, students engaged the class by reporting on the nature and functions of various poisonous plants and relating those characteristics to the plants in the story's description, and both faculty members and students discussed in depth the literary, moral, and philosophical facets of the story as well as the placement of the story in the development of science fiction as a burgeoning genre.

Another example was our study of Joan Slonczewski's *A Door into Ocean* (1986), in which a female race, the only inhabitants of an ocean planet, defeat a belligerent invading force by entirely peaceful means. Following our classroom activities related to this text, both faculty members and students participated in a Skype interview the author, who is a Professor of Biology at Kenyon College, and we all learned a great deal about both the physiognomies which she devised for her characters and the relationships they bore to actual biology, as well as the considerable influence of the time period in which she wrote the novel.

In addition, we provided film clips of movies, and as a class we all discussed the interplay between written and film genres, especially in light of historical contexts as well as advancements in film production. For instance, we read H. G. Wells' *The Time Machine*, and after our collaborative learning class session, we spent an additional class viewing clips of the novel's film adaptations which clearly reflected both the technological advancements in film making and the serious concerns weighing upon the society at the time of the film's production. A case in point: students found social and political concerns reflected in the alterations of crises depicted in the film, e.g., the fear of a nuclear exchange in the 1960 Cold War version versus the caricatured sadistic arch-enemy in the 2002 pre-Iraq War version.

Major Research Projects

Students were required to produce three major projects for the course: one individual written assignment and one team project produced in written and oral forms. The first assignment, a research paper in which each individual student addressed a work or works, was focused on assessing each student's independent knowledge and writing ability. Given the variety of students from the arts and sciences, we deliberately gave them leeway on how they wanted to approach this paper through scientific or literary lenses. This assignment gave us a sense of students' interests as well as their knowledge base in their major subject and their writing abilities.

Table 1
Student Assessment of Learning Gains

After completing the Science in Science Fiction course how much did you GAIN in the following areas?	No gains	A little gain	Moderate gain	Significant gain
1. Integrating your knowledge from disciplines in Science, Technology, Engineering, the Arts, and Mathematics (STEAM) to facilitate interpretation of literary works and to grasp implications in larger scientific, social, and other contexts beyond those works.	A	B	C 2	D 3
2. Demonstrating your critical thinking skills in interpreting texts.	A	B	C 2	D 3
3. Demonstrating your advanced written and oral communication skills required at the graduate level.	A	B	C 2	D 3
4. Demonstrating your ability to engage in thoughtful and informed class discussions.	A	B	C 2	D 3
5. Producing papers and other materials that illustrate research, interpretive, and communication skills.	A	B	C 2	D 3
6. Communicating ideas to others outside your discipline and your ability to collaborate with those in other disciplines.	A	B	C 2	D 3
7. Identifying and describing the relationships among science, art, literature and society.	A	B	C 2	D 3
8. Explaining the interplay among texts and multimedia works (film, art, interviews, etc.).	A 1	B	C 1	D 3

The course's major team research project, which included both a paper and a class presentation at the end of the semester, involved an examination of a subject from our readings from two or more interdisciplinary perspectives in the STE[A]M fields of Science, Technology, Engineering, the Arts (including literature, film, etc.), and Math. Since this was an interdisciplinary assignment, the faculty members grouped together students of different disciplines. Thus, this assignment included both collaborative and cooperative learning, and it was the most challenging for the students and us as well.

Results

Grades

Using the rubrics provided in the syllabus and at the end of this article, all three faculty members determined the grades for each assignment, as well as the final grade. Each of the faculty members graded each student's work individually. Then we met together, compared and rationalized assessments, and reached a final group consensus on each student's grade. Grades assigned to each student in the course were consistent with the standards delineated in the syllabus (Vanderbilt University Center for Teaching, 2016). Three students earned A's while two earned B's, so all produced either excellent or above average work in the course.

Student Assessments

At the end of the semester, following NIH regulations and with our Institutional Review Board (IRB) approval, all of the students participated in a Student Assessment of Learning Gains (SALG) survey, which measures "student reported cognitive growth" (Guadalupe, 1999, p. 499). Guadalupe Anaya's (1999) research concludes that "comparable results are obtained when using the college GPA and standardized test scores" (p. 499). The instrument included the assessment of individual Learning Gains, a section on the Impact of Taking Part in the Science Fiction Course, and a section of Open-ended Questions. In particular, the SALG asked students to assess and report on their own learning, as well as on the degree to which specific aspects of the course had contributed to that learning. This instrument sought not only data about student success in the subject matter, but also their measure of the success or failure of interdisciplinary learning in the course.

Learning Gains. "'Learning gain' is defined as the improvement in knowledge, skills, work-readiness and personal development made by students during their time spent in higher education" (Higher Education Funding Council for England, 2016). In the Learning Gains Assessment, students circle A, B, C, or D to provide their measure of learning gains. The cumulative results of our students' Learning Gains Assessment are provided in Table 1.

Table 2
Impact of Taking Part in the Course

Rate how much you agree with the following statements.	Strongly disagree	Disagree	Agree	Strongly agree
9. The diversity among faculty members' disciplines was useful to the class.	A	B	C	D 5
10. The discussion questions proved helpful in guiding a cross-disciplinary reading of the course texts?	A	B	C	D 5
11. The lecture material proved helpful in explaining the scientific concepts in the texts.	A	B	C	D 5
12. The teamwork (cooperative learning) proved useful.	A	B	C	D 5
13. The additional multimedia resources provided, e.g., the skype interview with Dr. Joan Slonczewski, videos, movie clips, etc, enhanced your understanding of the texts.	A	B	C	D 5
14. My participation in this project helped to prepare me for my future career.	A	B	C	D 5

Of the five respondents, three (60%) reported significant gains in each of the 8 categories on the chart while two reported significant or moderate gain in each category with an exception: one student reported no gain with category #5. This student cited his or her issue with team projects in the open-ended questions section as the reason for this difficulty.

Impact of Taking Part in the Science Fiction Course. The instrument below provided statements on the impact of the course on individual students, and students indicated their level of agreement with each statement, as indicated in Table 2.

All of the students (100%) strongly agreed with each statement in the survey.

Open-ended Questions. The Open-Ended Questions offered students an opportunity to include information that could not be provided by the instruments above. The questions and responses were as follows:

15. What would have made your experience in this course better?

- "I feel that the course was both diverse and well rounded. Overall, the course was fantastic. If I had to suggest anything, I would probably suggest adding more disciplines such as a psychology or sociology professor, maybe a lecturer?"
- "Maybe more interactive activities, PowerPoints, and presenting to each other."
- "Having a social science point of view."

16. Did you make other gains from doing this project that we didn't mention? If so, briefly describe.

- "I felt that the course material was very eclectic and covered a range of diverse material."
- "Now that I have completed the course, I will consider reading material outside of my discipline."
- "It is beneficial to reflect on other disciplines for a well-rounded education, but often majors become a way of life."
- "Yes, understanding how disciplines interrelate and provide an understanding how to explain these other disciplines."
- "I learned the importance of being able to explain yourself thoroughly on paper instead of sticking only to the facts."

17. In some detail, provide your thoughts on the planning and production of the interdisciplinary team projects (collaborative learning) for the course.

- "I enjoyed working with classmates of other disciplines. The only dilemma I had was that we dedicated so much class time to the group project that I was not able to focus on my individual project as much. I felt that the criteria and expectations were clearly expressed. No complaints."
- "The flow of this class is excellent and novel/short story choice is excellent."
- "The collaborative project should have been produced before the individual project. This would allow for a more concentrated effort to make points in

theory in the individual that may have been overlooked in the group."

- "It should have been longer time frame to work on team projects."
- "Okay, so that was a complete disaster. It shouldn't have been. In theory, it should have been a great experience, but a (possibly anomalistic) difference in competency and commitment levels – and maturity – created an experience that nearly outshone the positive experience of the rest of the course."

18. Please provide any additional comments or insights regarding the course and/or interdisciplinary teaching and learning.

- "Great job!"
- "Make sure the professors are on the same page when making decisions concerning dates things are due."
- "Do more interdisciplinary courses. Silos are damaging and ridiculous."

Discussion

The science content that was introduced to the Science in Science Fiction class was distinguished from what one might learn in a more typical STEM class in that some of the material was much more highly speculative, dealing with possible revisions to known laws of physics and biological reality. This included time travel, the existence and prevalence of extraterrestrials and parallel universes, and unusual reproductive practices. However, these fictional aspects allowed the instructors to introduce the actual scientific concepts and required students to contrast those with the speculative science presented in the texts. Additionally, the texts introduced realistic scientific aspects in sensationally creative ways, such as mutualistic symbiosis, evolution, gene expression, and microbiomes. The speculative science and the adaptation of actual science in creative ways effectively engaged the students in learning a variety of scientific topics that would otherwise have been less appealing and interesting.

In addition, anecdotal evidence suggested that there were students who, upon entering the course, clearly did not appreciate some academic disciplines, but these attitudes changed. For example, early in the semester, when the class was reading 18th century precursors to science fiction, one biology student acknowledged in a class discussion that she had no appreciation for fiction or allegory. However, based on unanimous responses in the survey data at the end of the semester, she had altered her opinion. Much later in the semester, in a follow-up discussion after the physics professor's explication of Greg Egan's "The Infinite Assassin," one English student acknowledged that she had never appreciated the arguments or aesthetic appeal of higher math before encountering Cantor's Diagonal Argument.

Students were given discussion questions to consider prior to class meetings and were expected to engage in discussion generated from these questions. Given the small size of the class, students could not easily avoid participating in the discussion. For a larger class it would be ideal for instructors to design a means for assessing participation. For example, each student can be assigned to lead a discussion on one or two specific questions for the entire class during the course of the semester. Alternatively, students can work in groups to answer questions with professors migrating from one group to another to join their discussions. Then the class as a whole can come together to share their responses. For the group project presentations students worked in pairs, but with a larger class size the projects can easily be adapted to groups of three or four. It is not recommended that the course be scaled to larger than 24 students given the writing and discussion intense nature of the course.

In addition to the small class size, this course also included a very diverse population of students, both academically and socially. The class included both graduate and undergraduates in different fields. Sixty-three percent were older than typical college students, 75% were women, 50% were underrepresented minorities, 50% had a strong science background, and 50% had strong backgrounds in the humanities. These differences added dimension to students' interpretations and discussions, thus broadening their overall learning.

The instructors selected the texts, and they were predominately written by white male authors (75%). This was attributed to the fact that historically science fiction has been dominated by white male authors. In the future it would be ideal to allow the students to choose some of the texts covered in the course with the expectation that they may select texts from a more diverse group of authors. Despite the fact that the texts were written by largely white male authors, the discussion topics generated in the course treated a wide range of issues and were covered from diverse points of view.

As is typically the case, some students were challenged with the collaborative project presentation. While collaboration is an essential skill to learn and practice, some students do not manage it well and require more time than expected to design and build a collaborative presentation. Two students commented on how the group project diverted their attention away from their individual research papers since they were required to spend a large amount of time collaborating with their team members. The collaborative presentations and the individual research papers were due at the end of the term. The authors recommend separating the due dates so that one assignment does not distract attention away from the other.

Limitations and Effects

Limitations include the fact that the course has been taught only once thus far. Also, some might ask how such a small class could address the wider problem of how to use the arts in STEM. However, one could argue that since most of our students are preparing to become teachers themselves, there may be a "multiplier effect" of their becoming adept at cross-disciplinary thinking as their teaching of their own students is affected.

As the SALG results show, the class had a positive or very positive effect on the students, with all students except one reporting significant or moderate learning gains, and 100% of students strongly agreeing that the course had significant impact on their learning. Students called the course "fantastic" with "eclectic" and "diverse material," and they noted that the "flow" was "excellent." In addition, the effect of the class on the three professors themselves would have to be considered significant given the low student enrollment. The class may well have broadened our views of other disciplines, students in other disciplines, and teaching in other disciplines. Thus, the effect of the course on the professors should also be measured when the class is taught again.

Conclusion

Science fiction is the literary form that unites both logic and intuition through language, and thus it provided the successful interplay of art and science in The Science in Science Fiction course. As pointed out by one student, silos can indeed be "damaging and ridiculous." Providing students with the opportunity to learn from an interdisciplinary approach certainly increases student engagement in the material and enhances students' learning, their ability to approach complex problems creatively, and perhaps their ability to contribute to society in meaningful ways.

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Appendix A
Course Schedule

Week	Text and/or Activity
1	• Discussion “August, 2026: There Will Come Soft Rains” by Ray Bradbury • Discussion “Micromegas” by François-Marie Arouet (Voltaire)
2	• Discussion “Rappacini’s Daughter” by Nathaniel Hawthorne and comparison to Poison Ivy comic from the *Batman* series
3	• Discussion *Frankenstein* by Mary Shelly and comparison to *Young Frankenstein* (film clips)
4	• Discussion *The Time Machine* by H. G. Wells
5	• Discussion *Starmaker* by Olaf Stapleton
6	• Discussion *Starmaker* by Olaf Stapleton
7	• Discussion *A Door into Ocean* by Joan Slonczewski
8	• Discussion “Blood Music” by Greg Bear (short story adapted from the novel Blood Music) • Group Collaboration time (project planning 1)
9	• Discussion “Blood Music” by Greg Bear (short story adapted from the novel Blood Music) • Group Collaboration time (project planning 2)
10	• Discussion “The Hundred Light Year Diary" by Greg Egan • Discussion "The Infinite Assassin" by Greg Egan
11	• Discussion "The Infinite Assassin" by Greg Egan • Discussion "Learning to be Me" by Greg Egan by Greg Egan
12	• Discussion “All You Zombies” by Robert Heinlein • Discussion “The Last Question” by Isaac Asimov • Individual Research Papers Due
13	• Group Collaboration time (project preparation 1) • Discussion “The Ones Who Walk Away from Omelas” by Ursula LeGuin
14	• Discussion “A Simple Greeting” by Caw Miller • Discussion “The World Without Us” by Alan Weisman • Group Collaboration time (project preparation 2)
15	• Final Project Presentations on May 3rd, 5-7 p.m.

Appendix B
Discussion Rubric

Discussion Rubric				
	Excellent	**Good**	**Marginal**	**Unsatisfactory**
	100	**82**	**64**	**0**
Promptness and Initiative	Consistently starts discussions; demonstrates good self-initiative and participation	Starts some discussions; responds/participates most discussions	Rarely participates; limited initiative	Does not participate
Delivery	Consistently uses grammatically correct language	Few grammatical errors in speaking	Numerous grammar errors in speaking	Grammar errors in every delivery
Relevance	Consistently focuses on discussion topic; connects with additional references related to topic	Frequently focuses on relevant discussion content; prompts further discussion of topic	Occasionally speaks off topic; discussion efforts are brief and offer no further insight into the topic	Consistently speaks off topic
Expression	Expresses opinions and ideas in a clear and concise manner with obvious connection to topic	Opinions and ideas are stately clearly with occasional lack of connection to topic	Unclear connection to topic evidenced in minimal expression of opinions or ideas	Does not express ideas
Contribution to the Learning Community	Is aware of needs of class community; frequently attempts to motivate the group discussion; presents creative approaches to topic	Frequently attempts to direct the discussion and to present relevant viewpoints for consideration by group; interacts freely	Marginal effort to become involved with group	No contribution

Appendix C
Team Research Project Presentation and Paper Instructions

The team research project will be a collaborative examination of a subject or subjects from our readings from two or more disciplinary perspectives in the STE[A]M fields of Science, Technology, Engineering, the Arts (including literature), and Math. **Students in different fields of study** will blend their research, analytical, and writing skills to produce their project, which could be the interplay of literary and scientific elements of a work, an analysis of the science and society of a given work in its time period, a comparative study of two works, the historical context of a work, the cultural contexts of a work, how a work is structured (plot twists, images, etc.) to enhance a particular interpretation of the work, or a particular theme dealt with in two or three works, or any range of additional possibilities. Topics must receive the approval of the teaching team. There are two components to the project: 1. Your team must present your project orally. 2. Your team must also provide a written report of the project.

Project Proposal

Your team must submit an abstract (summary) of your project and for your instructors to review and approve. The abstract must include the following components and should not exceed one page written in 12-point font:

1. Authors
2. Presentation title (not more than 100 characters in length)
3. Your objectives and description (be certain to include the literature you will be covering)
4. References

Research Guidelines

- You can use books/stories that we did not cover.
- Your individual research papers cannot cover the same texts that your team projects cover.
- Your presentations will be 15-20 minutes (you will have 5 minutes for Q&A after you present), and the Team Presentation grading rubric is below:

Team Presentation Grading Rubric				
	Excellent	**Good**	**Marginal**	**Unsatisfactory**
Content **Excellent = 30** **Good = 22** **Marginal =15** **Unsatisfactory = 0**	Information is appropriate with well-developed multimedia materials	Information is appropriate with main points somewhat developed	Information is off topic and development is poor	Information is very shallow or nonexistent with no development, or the presentation is not delivered at all
Organization **Excellent = 25** **Good = 19** **Marginal =10** **Unsatisfactory = 0**	Main points are clearly focused, well connected, and well organized	Frequently focuses on main points, but there are organization problems	Disorganized with content and/or speaks off topic extensively	Displays complete disorganization
Physical Expression and Style **Excellent = 25** **Good = 19** **Marginal =10** **Unsatisfactory = 0**	Displays engagement with topic and makes frequent eye contact	Displays some engagement and some eye contact	Topic engagement and eye contact are minimal	No topic engagement or eye contact
Vocal Delivery and Language **Excellent = 20** **Good = 15** **Marginal =10** **Unsatisfactory = 0** **Total ________**	Voice is clear and energetic, and there is consistent use of grammatically correct language and no hesitations.	Voice is adequate for the presentation but not engaging, and there are a few grammatical errors in speaking.	Voice displays little energy, and there are several grammar errors in speaking.	Voice has no energy, and there are major grammatical errors throughout.

Team Paper Guidelines

Papers must be composed using the default margins (1") and standard type (Times New Roman or Ariel 12) of MS Word. It must be 10-12 pages of text in MLA-style format **plus** a page or pages of Works Cited. The paper should actively use and cite at least ten sources outside our text itself, including at least two Internet sites and two traditional texts. Papers will be evaluated according to CSU Writing Guidelines.

Your particular choice of work(s) must be on the syllabus. Students in different fields of study will blend their research, analytical, and writing skills to produce their project, which could be the interplay of literary and scientific elements of a work, an analysis of the science and society of a given work in its time period, a comparative study of two works, the historical context of a work, the cultural contexts of a work, how a work is structured (plot twists, images, etc.) to enhance a particular interpretation of the work, a particular theme dealt within two or three works, or any range of additional possibilities. The team paper is a written document that models your team research project presentation (described above) and will be assessed according to the CSU Writing Guidelines

CSU Writing Guidelines Grading Rubric

Content: 35% of the paper grade ________

- Fulfillment of the assignment's content requirements.
- Clear, focused topic
- Demonstrated familiarity with the subject matter.
- Range and quality of knowledge.
- Depth of assimilation and understanding of the subject matter.
- Sufficient and suitable content to support and develop ideas.
- Awareness of audience

Organization: 30% of the paper grade ________

- Clear introductory, body, and concluding paragraphs.
- Unity and coherence.
- Support for focused topic
- Transitions that move the reader from key point to key point.

Mechanics, Grammar and Style: 35% of the paper grade ________

- Format
- Punctuation
- Sentence Structure
- Grammar and Usage
- Competent use of standard English
- Style
- Diction

Total: ________

Comments:

Grading Rubric below:

Appendix D
Individual Research Paper Instructions

The individual research paper may address a work or works through the lens of STE[A]M or through another framework which interests the writer. Your possible subjects/treatments might be the interplay of literary and scientific elements of a work, an analysis of the science and society of a given work in its time period, a comparative study of two works, historical context of a work, the cultural contexts of a work, how a work is structured (plot twists, images, etc.) to enhance a particular interpretation of the work, or a particular theme dealt with in two or three works, or any range of additional possibilities.

Topics must receive the approval of the teaching team. For this, you must submit an abstract (summary) of your project and for your instructors to review. The abstract must include the following components and should not exceed one page written in 12-point font:

1. Research paper title (not more than 100 characters in length) *[Note: this can be modified later as we know it can be challenging to develop a perfect title early in the process.]*
2. Your objectives and description (be certain to include the literature you will be covering)
3. References

Research Paper Guidelines

1. A student's individual research papers cannot cover the same work(s) as that student's team research paper/presentation.
2. Papers must be composed using the default margins (1") and standard type (Times New Roman or Ariel 12) of MS Word. It must be 10-12 pages of text in MLA-style format **plus** a page or pages of Works Cited. The paper should actively use and cite at least ten sources outside our text itself, including at least two Internet sites and two traditional texts.
3. Be sure that your internet sources are authoritative sources.
4. Your particular choice of work(s) must be on the syllabus.
5. Your paper will be assessed according to the CSU Writing Guidelines Rubric.