Journal of Humanistic Mathematics

Volume 11 | Issue 1 January 2021

Humanistic STEM: From Concept to Course

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Abstract

Blending perspectives from the humanities and STEM fosters the creativity of all students. The culturally implicit dichotomy between the two meta-disciplines can be overcome with carefully designed courses and programs intent on doing so. The why and how of doing so through an online course is described with qualitative evidence of the success. Future plans for a full slate of such course and a virtual community are discussed.

Keywords: STEM, humanities, cross-disciplinary

1. Introduction

In "What is Humanistic STEM and Why Do We Need It?" [1], we (DBT and BLW) defined Humanistic STEM (H-STEM) as "blending the study of science, technology, engineering, and mathematics with interest in, and concern for, human affairs, welfare, values, or culture." This blend, we argued, has the potential to elevate the humanities among STEM-focused students. Additionally, H-STEM can provide students with a unique combination of desirable general education competencies, specifically focusing on the critical thinking and communication skills that their future employers demand.

In March 2019, we were able to provide a proof-of-concept of the H-STEM idea in a co-developed and team-taught upper-level humanities course:

HUMN 333: How Fiction, Film and Popular Culture Represent Science and Mathematics. HUMN 333 was delivered asynchronously online in our typical nine-week format. With 18 students in the term it was launched, HUMN 333 was also well-suited to assessment, enabling us to strategically evaluate innovative cross-disciplinary approaches, such as team-teaching or the infusion of STEM contexts in literary analysis, prior to fully utilizing these methods within the proposed additional courses in the new minor.

This course will serve as the anchor for an eventual five-course minor in Humanistic STEM. Moreover it can serve as the upper-level humanities general education requirement for all students. An additional outcome is the ignition of student interest in additional interdisciplinary, humanities offerings while fulfilling a general education requirement.

As we developed the rationale for the course, it was important to make a clear distinction between H-STEM and other, similar attempts to integrate arts into STEM curriculum. This step was essential, both for our own understanding of the project and to clearly define the pedagogical framework under which the entire H- STEM project would operate. Specifically, we sought to create a clear distinction between Humanistic STEM and a variety of approaches commonly known as STEAM (Science, Technology, Engineering, the Arts and Mathematics).

STEAM, as Martin *et al.* [5] note, was introduced, in part, to help counterbalance the increased focus on STEM subjects and the decline in arts education in the United States for over a decade. Additionally, STEAM often focuses on targeting and engaging minority and female STEM students. For example, Kant, Burckhard, and Meyers's empirical study of Native American girls [4] explains that STEAM education "is one way of promoting more interest in science, technology, engineering, and mathematics (STEM) studies and careers among indigenous students." Another empirical study by Quigley and Herro [8] concludes that, "one of the goals of STEAM is to involve the arts in order to increase the participation of students who are traditionally absent from STEM."

Despite these commendable motivations, however, the construct and framework of STEAM do not serve our purposes effectively. Initiatives centered on STEAM integrations have mainly been limited to K-12 contexts.

They have also often focused on the arts to the exclusion of the humanities [6]. Specifically, many STEAM efforts focus exclusively on performing or visual arts. Furthermore, in its 2018 report *The Integration of the Humanities and Arts with Sciences, Engineering and Medicine in Higher Education: Branches from the Same Tree* [6], the National Academies of Sciences, Engineering and Medicine warn that "focusing on which disciplines are counted in (or out) has the potential to distract from the question of what educational aims should inform curricula" (page 23).

There is also a legitimate concern that STEAM often *adds* the arts to STEM without an attempt to *blend* the disciplines in any way that exposes students to the value of multiple perspectives or methodologies. Perignant and Katz-Buonincontro [7] perceptively note that scholars must shift their language from one that "adds arts to STEM" to describing STEAM as a pedagogical approach that integrates five disciplines. Furthermore, a focus on product over process has hampered the potential of STEAM as a viable way to elevate both meta-disciplines. As Sternberg and Williams [11] explain, many educators struggle to understand that creativity development is fostered, not through the art materials or products, but through a process of exploration, play, risk-taking, making mistakes, self-evaluation and feedback.

While the Humanistic STEM approach does include the addition of activities (or "infusions") to existing courses, its primary focus is the inclusion of interdisciplinary perspectives. H-STEM attempts to integrate ideas and issues from diverse academic disciplines (particularly across meta-disciplines) in order to expand students' capacity for analysis and critical thinking. H-STEM explores how the humanities disciplines perceive, interpret and discuss the seemingly diametrically opposed STEM disciplines. Pairing literary analysis with proof-writing or discussions of graphical excellence as part of persuasive public speaking, for example, truly blends perspectives usually addressed in separate courses, especially in general education. H-STEM students will be able to apply interdisciplinary knowledge, concepts, skills and methods of inquiry attained in academic settings to produce creative responses to complex problems and situations, allowing them to blend their technical competence with the creative and critical thinking skills that an increasing number of employers are stating as essential for continued success in any field.

It is with this clear distinction between STEAM and H-STEM that we began the development process for the anchor course in our H-STEM project: HUMN 333.

2. Course Goals, Learning Outcomes and Assignments

The course description for How Fiction, Film and Popular Culture Represent Science and Mathematics states:

> Students will explore representations of mathematics and science in literature, film and popular culture. Traditional media (books, drama, film, and television), as well as web-based media (webcomics, YouTube series, and podcasts), will be the venues in which students discuss the portrayal of the lives of scientists and mathematicians as well as scientific theories and mathematics concepts.

The prerequisites for this course specify that students take the university's basic composition course (ENGL 123) as well as at least one mathematics course. This requirement ensures that students will have exposure to the basic vocabulary from each meta-discipline and the ability to discern whether mathematical and scientific concepts are related to audiences in a coherent and accurate way. Additionally, students are required to blend humanities methodologies (including content analysis, historical research, and media analysis) with critical thinking about mathematical and scientific content.

The goals of the course are described in the course syllabus as follows:

> This interdisciplinary experience will allow students to integrate ideas and issues from diverse academic disciplines in order to expand their capacity for analysis and critical thinking. They will learn the language and methodologies commonly associated with various disciplines, both to understand their commonalities and also to appreciate their differences. They will learn how one discipline (humanities) perceives, interprets and discusses another (science and mathematics).

These goals clarify that students will be exposed to multiple methodologies associated with the meta-disciplines of STEM and humanities, specifically to increase understanding of the other, rather than to engage in siloed, solipsistic self-exploration.

The course learning outcomes state that students will be able to do the following:

(a) Evaluate and write about the accuracy of the scientific/mathematical concepts depicted in works of fiction in various media.

(b) Engage in integrative learning by making connections across disciplines.

(c) Demonstrate critical thinking skills in discussions of literary elements.

(d) Recognize and discuss how science/mathematics and the humanities influence each other in the intellectual environment of their time.

(e) Demonstrate in writing an understanding of the portrayal of professional ethics in works that represent science and mathematics.

These outcomes highlight the expectation for students to be able to use writing to explore and explain how science and mathematics are represented and whether they are represented accurately. They are asked to look at the full intellectual context in which discoveries are made and ideas are born.

Assignments in the course include active participation in discussions threads. Additionally, comprehension questions are imbedded in weekly presentations. Students produce "media journals" documenting their own H-STEM encounters. They write two analytical papers: one on an annotation from *Frankenstein: Annotated for Scientists, Engineers, and Creators of All Kinds* [9] and another of STEM and humanities elements of a film of their choice. As Keith Devlin notes in his foreword to Sklar and Sklar's *Mathematics in Popular Culture*, "Though many of the examples of popular culture discussed can be (and frequently are) dismissed as 'shallow,' the very fact that mathematics lies just beneath the surface indicates that even 'mass entertainment' can have a hidden depth" [10, page 1]. Students are encouraged to find and explore this "hidden depth" in the films they select.

The final project asks students to create an H-STEM "trailer" for a proposed project (such as a film or novel) that will feature a humanities STEM blend. Details on these tasks, and student responses to some of these assignments, can be found below.

While developing this course, we felt that the traditional course design focused on a single teacher taking the learner through weekly modules in a linear progression did not best support an approach that demands an explorer's mindset. Therefore, we worked to create a plan that would encourage students to fully experience all features of the class rather than to retreat to the aspects and assignments they found most familiar.

3. Design Strategy

The typical strategy for course design features modules presented in a highly structured (and predictable) series of readings and activities. Students become accustomed to diligently working from one activity to the next, and they quickly learn which items require less attention (and which can perhaps be avoided altogether). One of the initial design strategies for this course was to move away from this presentation of module materials and create an "essential elements" screen that functions as a thematic infographic with clickable areas, meant to create interest in the week's central topic and compel users to explore all elements of the course (see Figure 1). In Module 1, for example, this page centered on the universe and featured a photograph of the Milky Way, the painting "Starry Night" by Vincent Van Gogh, a link to orchestral suite *The Planets* by Gustav Holst and a quotation by mathematician and philosopher Gottfried Wilhelm von Leibniz. The goal of all of these module landing pages was to reinforce the essential course goal of creating multiple lenses of inquiry by showing the same concept or theme as represented by mathematicians, scientists, artists, writers, philosophers and even musicians.

Each module landing page includes four tabs. The "Engage" tab displays the "Humanities & STEM" infographic. The "Learn" tab includes the lecture materials. Most modules contain three short videos, each approximately three minutes long. Two of these videos — one recorded by each instructor — approach the week's topic from a disciplinary perspective.

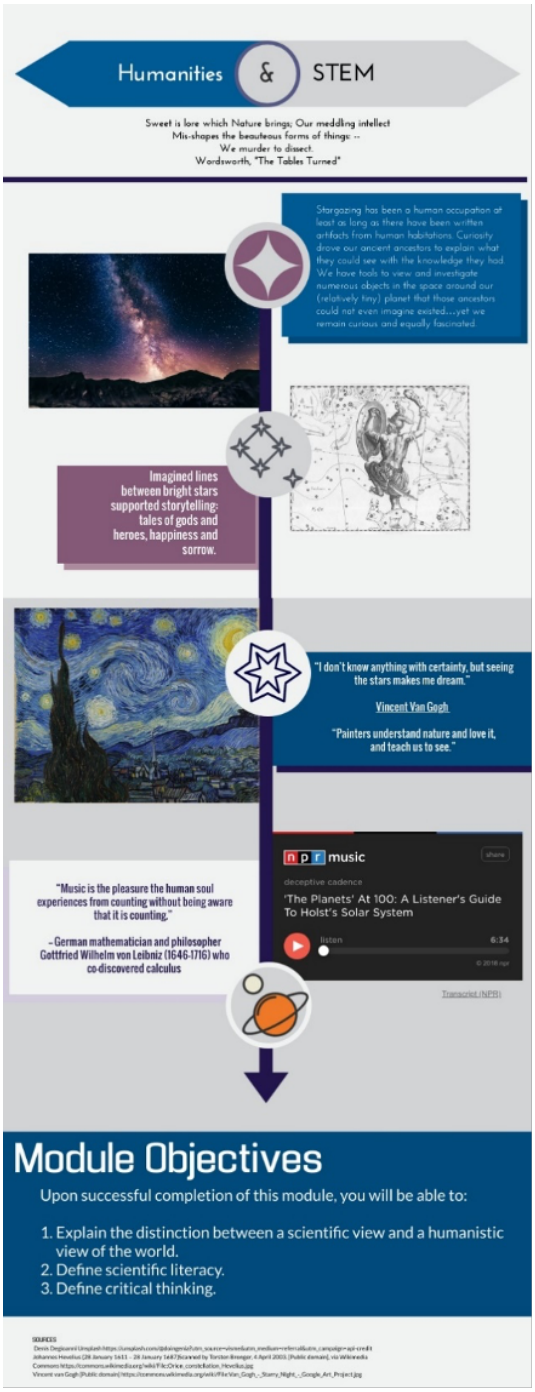

Figure 1: HUMN 333 Module 1 landing page.

For example, Module 2 focused on Volume 1 of *Frankenstein* features a humanities-based video on the history of the novel while its STEM-based video discusses anatomy and alchemy. Then, both instructors together produce the third video (in this case, an examination of the "lab scene" in Shelley's novel) which blends the humanities and STEM perspectives. This series of blended videos are interactive in nature as they require students to answer questions at various intervals in order to move to the next section of the video. These videos model the interdisciplinary thinking that is expected of the students. Rather than looking at a topic through one specific, comfortable disciplinary lens, they are required to see how the same idea might be interpreted in multiple ways (see Table 1).

Table 1: Lecture descriptions by module in HUMN 333

Module	Assigned Content	Humanities Mini-Lecture	STEM Mini-Lecture	Blended Mini-Lecture
Intro		n/a	n/a	Be a Leonardo!
1: The Odd Couple	When I Heard the Learn'd Astronomer	Enlightenment vs. Romanticism	Astronomy	Natural Philosophy
2: IT'S ALIVE!!!	*Frankenstein*, Vol. I	Vol. 1: Narrative construction	Alchemy & Anatomy	Ethics & Electricity
3:What's in a Name?	*Frankenstein*, Vol. II	Vol. 2: The creature as storyteller: What is monstrous?	Geography & Meteorology	Maps & Setting
4: Don't Be Like Victor	*Frankenstein*, Vol. III	Vol.3: Victor as narcissist?	Ship engineering & Polar Exploration	Complexity of Novel vs. Film & Ethics of Human Experiments
5: Science in Storytelling	Clips from films such as *Gattaca* and *Jurassic Park*; "A Sound of Thunder" (short story)	Ethics in Reproductive Science	Time & Genetics	Forensics in TV
6: Hidden No More	*Hidden Figures* Movie	Race & Gender Barriers	Astrophysics	Space Race
7: Scientists are People Too	Clips from *The Man Who Knew Infinity* and *A Beautiful Mind*	Tropes & Stereotypes	20th Century Technology	Breaking the Stereotypes
8: STEM in Popular Culture	TED Talks, Science Blogs, & TV	New Genres	Black Holes	Game Shows, Contests, & Competitions
9: Revenge of the Nerds	Clips from *The Theory of Everything*, *Cosmos*, & *Bill Nye the Science Guy*	n/a	n/a	Are You a Leonardo?

The "Converse" tab contains each week's discussion questions. Most "Converse" forums include three questions, and students are assigned by last name to a specific question for their initial post. The two required follow-up posts must be to the other prompts, requiring students to engage with all three discussion questions during the module week. Again, students are not permitted to relax within the comfortable climate of their own meta-discipline and are nudged to participate in conversations they might otherwise never encounter. The "Accomplish" tab includes the week's deliverables, including a "Get Your Ticket" to the next module — a series of questions that require students to examine all components of the module. One student commented specifically on the design: "The approach was different and seemingly simple, but the knowledge obtained was greater than expected."

4. Course Content

Once we determined how to execute the course design, we then turned to selecting course materials that would work best with the mission of the class. As Capezzi and Kinsey [2] cleverly note, "we want[ed] to communicate to our students [...] that mathematics and literature interact in wonderfully weird and humorous ways" (page 69). Fortunately, the 200$^{\text{th}}$ anniversary of *Frankenstein* saw a renewed interest in Mary Shelley's novel, its longevity and its multidisciplinary appeal. David H. Guston, Ed Finn and Jason Scott Robert's version of the work [9] — published with MIT Press — is "annotated for scientists, engineers and creators of all kinds." The specific focus of the annotations promised to provide needed context for 21$^{\text{st}}$-century students but, even more importantly, could generate a strong interest among our STEM-focused students. The annotations became an indispensable part of how the novel was presented to the class. Where we typically would have been open to students purchasing any version of the text that was easiest to obtain, here we absolutely insisted on this specific edition of the work. Rather than compose a more traditional literary analysis based on typical elements of fiction, students were asked to select an annotation for additional research. The papers that resulted were on topics as diverse as manifest destiny, bullying, retribution, Galvanism, and Freudian psychology. Students were also asked to analyze and discuss adaptations of the novel in film and on stage and asked to ponder why so many of these efforts fail to adequately represent Shelley's work.

Even more surprising was the number of students who counted this assignment as one they enjoyed most. After all, we could easily see the appeal of the "pop culture" components of the course, but we figured that a 19th-century novel would require some true salesmanship on the part of the instructors; and in the pre-term survey, exactly half of the students responded that they rarely read works of fiction. Indeed, many admitted they were not thrilled initially by starting the course with a 200-year-old book, but quickly realized its relevance, with one student stating that aspects of the novel "are as valid now as they were then." Another student admitted, "Reading *Frankenstein* took a bit of adjustment of the wiring at first, but was enjoyable afterwards and certainly did help to bridge the gap of understanding the relationship between humanities and STEM." Yet another student commented, "Reading *Frankenstein* was a treat and an outstanding idea which showcased the fact that this relationship [humanities and STEM] has been around for a good portion of our recorded history. No matter where you fall on the humanities/STEM spectrum, conducting yourself as a good and ethical person is a prerequisite."

To explore the legacy of works such as *Frankenstein* —arguably the first science fiction novel — the course turns to more current examples of the genre. In this "Science in Storytelling" module students read Ray Bradbury's "A Sound of Thunder," a science fiction short story published more than a century after Shelley's novel. They also examine several film and televisions clips, including *Jurassic Park*, *Gattaca*, *The X-Files*, *Westworld*, and even *Breaking Bad*. They are asked to comment on the accuracy of the science as presented and also prompted to explore ethical issues in their selected works.

The one full-length movie the whole class was required to watch, *Hidden Figures*, fit our Humanistic STEM concept as perfectly as Shelley's novel had. To add synchronous elements to the course, we organized a virtual viewing party and enjoyed the side conversations in the chat box during the movie, pointing out the mathematical and technical aspects of the Mercury project as well as the race and gender issues that pervade the movie because of its historical setting. Clips from other movies about real scientists and mathematicians — such as *A Beautiful Mind*, *The Man Who Knew Infinity* and *The Imitation Game* — drove the discussion of stereotypes and tropes. For their second analytical paper, students chose their own STEM-based movie to watch and analyze at least one scene that demonstrates the blend of humanities and STEM we had been discussing for six weeks.

Apollo 13 was the most popular non-fiction selection, which is not surprising at our aeronautical institution. Other popular choices included *Interstellar*, *Twister*, *Minority Report*, and *The Martian*. Several specifically mathematical movies such as *Good Will Hunting*, *Moneyball* and *The Matrix* were chosen, aligning with the commentary offered by the mathematician authors in [10]. Students also, however, focused on humanities concepts in their chosen films. In addition to exploring mathematics in *The Matrix*, for example, they could also discuss its connections to philosophy. In the self-reflection at the end of the course, one student commented specifically on this element of the class:

> "After *Frankenstein*, we started to get more into TV and film where I was able to choose topics that I was already familiar with. This opened up a new appreciation for how humanities and STEM worked together. After going back through these shows and films, I was able to see them from a different point of view, which made me think more about the humanities side of it. This is because before, I would just assume that the interactions were just part of the story, but not how the interactions actually affected the different characters. Once I could see that, it really showed how connected humanities and STEM really are. Now that I can see those connections, I feel that I am more aware of them throughout the different media."

The term wraps up with a couple of weeks on television shows (fiction like *NUMB3RS* and *Big Bang Theory* as well as non-fiction like *Bill Nye the Science Guy* and *Cosmos*), science blogs, TED talks, podcasts and academic competitions. One of the last blended lectures features DTB's enthusiasm for competitions such as *Who Wants to be a Mathematician* at Mathematicon and *Jeopardy* as well as BLW's kudos to recent winning teams at the International Mathematics Olympiad. Students predictably enjoyed this focus on popular culture, with one commenting, "I have already recommended this course, because it was one that I will never forget. I do not think I will ever watch a television show or film without making the connection."

5. Successes

5.1. Before and After: Surveys vs. Reflections

The pre-term survey was our way of judging the expectations and previous experiences that the students would bring to the discussions. The final discussion assignment is a reflection on the whole course that ties back to some of those initial survey questions to assess if we accomplished our goals. Of the 15 students completing the reflection assignment (out of 18 enrolled), 11 of them used the word "enjoyed" to describe their experience with all or a significant part of the course such as reading the novel, writing the analytical papers or the high level of engagement in the discussions. This was often in the context of how their expectations had been met or not met; even the four who did not specifically say "enjoyed" said that their expectations were met or exceeded.

"I absolutely loved this class! My expectations were well exceeded," came from an Environmental Science student already convinced that the study of humanities is important to a STEM degree/career. More telling is the Engineering student who began the course with "Humanities is not very important. I think degree programs should focus on courses that prepare students for their future careers" but ended with "Little did I know, this course would have the most impact on me out of any other course that I've taken." A student from the Interdisciplinary Studies degree program said at the beginning of the course that not only did he avoid reading novels but also avoided movies and television with STEM themes. In his course-ending reflection, he demonstrated that the course had reached him in exactly these two places: "I had never read *Frankenstein*. But I loved it!... The films that were part of the class demonstrate that STEM is and will be around us from now on. The appreciation of individuals from all types of [back]grounds can contribute to the new technology era. That successful scientists can benefit from humanities."

"Just another humanities course," lamented one student in the pre-course survey. Another seemed concerned with the theme, stating, "Math and humanities have always seemed rather separate languages to me." Self-reflections, however, revealed quite a different attitude. One student commented, "Before this class, I never knew what STEM and humanities was, and I never would've guessed that they had an inseparable relationship."

Finally, one student summarized the experience: "I didn't realize how deeply STEM and the humanities were actually related. I'm really proud of how much I've learned and taken away from this class by exploring a different side of humanities." Not only did students come away fully understanding the H-STEM concepts of blending multiple disciplinary perspectives to increase understanding, but many felt academically and personally enriched by the course.

5.2. Becoming Leonardos and Talking Back to Walt Whitman

To introduce the unique H-STEM idea to students, we filmed a rather informal "course trailer." In the short video, we jokingly ponder our disciplinary differences,[1] asking how we can even possibly be friends with such dissimilar interests and background. The goal of the video is to reveal the perception that someone is either a "math/science person" or an "arts person." We reveal these distinctions as a false dichotomy that was exacerbated by the Romantic response to the scientific revolution and the latter's focus on reason over imagination, a dichotomy that became most prevalent in the 19^{th} century. We encourage students to instead reach back to polymath Leonardo da Vinci who was — among other things — an inventor, artist, musician, writer, astronomer, and mathematician. We declare ourselves "Leonardos," and encourage students to "Be a Leonardo."

Little did we realize that students would embrace this idea of being a Leonardo as a theme for the class. They often mentioned becoming a Leonardo in their discussions, and some even discussed their "Leonardo moments" in their media journals. We had no idea that this casual introduction to H-STEM would resonate with students much more than any "academic" attempt to explain our goals for the project.

Because we realized it was essential that students could grasp the cognitive shift required in this course, we placed the course trailer before the first module as required watching, but we also had students jump right into their own exploration of STEM/Humanities dichotomies. To that end, the first module simply had them explore Walt Whitman's 1867 poem "When I Heard the Learn'd Astronomer." In this poem, the speaker (presumably a poet),

[1]DTB is a humanist and BLW is a mathematician, by training and vocation.

attends a lecture by a celebrated astronomer. Upon seeing the mysteries of the universe broken down into "charts and diagrams," he admits becoming "tired and sick," leaving to simply look "up in perfect silence at the stars."

Students perceptively comment on how the poet sees the universe (represented by the "mystical moist night-air") and how the scientist attempts to capture that experience and represent it in "proofs" and "figures." They describe a need for both perspectives. Many even discuss how both the scientist and poet are attempting to answer the same elusive questions, each using their own unique language. After such an intelligent, insightful discussion, it was clear that students were ready for the world of H-STEM.

5.3. Students as Storytellers: Media Journals and H-STEM Trailers

Students were required to produce four media journals to demonstrate that they could see items and events in their everyday lives that blended aspects of humanities and STEM. Many had commented in the first week's video introduction that they were uncomfortable recording themselves and that discomfort persisted through the first and second journal submissions. Each of the instructors made an example: a podcast about an immersive art experience and a screencast of a visit to Machu Picchu. There was a fairly even split between podcasts and screencasts in the students' technical choice for presentations. The topics chosen widely varied as seen in Table 2. At least one podcaster expressed a desire to continue his series even beyond the class.

The final project in the course increased the technical complexity by requiring a visual recording to create a trailer (or pitch) for a movie or some other event that would blend humanities and STEM. Of the nine students who had been opting for podcasts for media journals, five took a big step into video recordings. Two of these recruited friends and family to be in their cast. All but two of the consistent screencasters switched to video for this assignment.

There were movie trailers for two comedies and two action/adventure films. Also, two pitches for courses: one to teach military veterans how to use the internet for finding benefits and one for surviving an apocalyptic event. The latter would be of use for all the dystopian movies that were offered: "A Burning World," Eyes in the Skies," "The Human Plague," "Dismantled," and "Doomsday Preppers." The remaining five submissions were documen-

Table 2: Media Journal topics in HUMN 333

Architecture	Films & Books	Children	Tech
Tesseracts	*Captain America*	STEM NOLA	Electric Cars
Giza Pyramids	*Artificial Intelligence*	STEM in Youth	Space X
Viking Sunstone	*Logan's Run*	Andrews Air Show	Formula One Racing
Infinity Pools	*The Rocketeer*	STEM in Children's TV	3D Printing
Gila Cliff Dwellings	*Interstellar*	Houston Children's Museum	Alpha-Sim
Moody Mansion	*Flubber*	Lego Innovation Kit	Medical Devices: eSight, Exo, Uni
Stonehenge	*Star Wars: A New Hope*	Video Games	Communications
Winchester Mansion	*Contagion*	Harry Potter World	Hubble Telescope
Roman Amphitheater	*Screenagers*	Kids as Scientists	Amazon Alexa
	The Big Bang Theory		Lifelogging
	Lost		
	Superheroes		
	Mentats of Dune		
Art	**Nature**	**Music**	**Jobs**
Cloud Gate (The Bean)	Photo of Black Hole	Math Behind Music	Air Force Weapons Maintenance
Fabian Oefner	Sunflower Field	Mars (The Planets)	Rhino Monitoring
Arcosanti Mandala	Carlsbad Caverns	Science Behind Music	UAV Mishap Investigation
Anime	Sublime & Picturesque		Land Navigation
Equation Artistry	Biosphere 2		
	Exotic Travel		

taries on clean water, child labor, nanobots for art theft, a grandmother who had been a WWII engineer turned artist, and quantum physics evidence for mythological creatures. Students fully embraced their new role as H-STEM storytellers.

5.4. Team Development and Teaching

The end of course student surveys given through all university courses included another opportunity for us to receive student impressions about course design and delivery. Sixteen of the eighteen students completed this survey. Four of the seven prompts related to the instructor had unanimous top ratings (strongly agree) on the Likert scale and the few that did not chose that top rating on the other three were in the next category (agree). Additionally, seven students made the effort to include open-ended responses that were entirely complimentary.

One student said, "[The instructors] are both extremely knowledgeable in their fields, which is obvious throughout the course." Another expanded on that with, "Their backgrounds brought different perspectives to the topics and made the class more fun and interesting." Easily our favorite student statement, however, is the one that puts a great label on exactly what we had hoped for when we began this project:

> I liked the *Gemini* concept behind teaching this course and appreciated the extent to which the professors engaged in the discussions. *Their suggestions and comments led students to consider alternative avenues of thought* and were quite positive. [emphases added]

We want to note that the team-development/teaching aspect is absolutely essential for a truly interdisciplinary experience for the students. We were teamed with a skilled course designer who was eager to use the alternative module format and include new (at least to us) technologies to deliver the infographics and interactive video lectures with the aid of an instructional technologist. Additionally, one of the aspects of the class that we determined might be an obstacle (the asynchronous delivery) actually ended up being one of the ways that we were best able to provide that interdisciplinary experience and best leverage the team-teaching approach. "This was the most successful online class I've taken at Embry-Riddle for interaction!"

There were concerns that what we wished to achieve perhaps could not be accomplished in an online course. Examples of online course development involving more than one faculty member are rare at our institution, and online team teaching is nonexistent. While we were teaching the course, however, we found the process much smoother than expected. Unlike a traditional classroom where there are clear distinctions between one instructor and the other (after all, only one can talk at a time), the democratic nature of the online discussion board allows for multiple and simultaneous posts by instructors and students in a forum where all voices can be heard. As instructors, we made it a priority to comment specifically on posts that were outside the boundaries of our primary meta-discipline. This modeled both the level of engagement we expected from the students as well as the fact that we wanted them to speak to issues where they did not necessarily consider themselves experts. We also wanted to deliberately keep students from associating all STEM content with one instructor and all humanities content with the other and, as a result, closing their minds to half of the perspectives offered in the course. Chabrán and Kozan, who in [3] discuss their experience in a team-taught mathematics and film course, write: "We also noticed that while the science students remained engaged during the literature lectures or activities, it was not the case for the non-science students during the mathematics lessons" (page 338). We hoped to avoid this issue by having the

humanities instructor fully engaged in the STEM discussions and the STEM instructor participating wholeheartedly in the humanities discussions, and thus reinforcing relevance outside of the disciplinary context.

6. Challenges

6.1. Team Development and Teaching

As we state above, at every level of the approval process, various entities expressed concerns that our lofty ambitions could not be accomplished, especially in an asynchronous course. Our institution rarely has involved more than one faculty member in course development, and online team teaching is nonexistent. Expressing our vision to both a designer and a technologist required some repetitions that slowed the work. We actually began teaching the course before the last few modules were completed due to the delays in communication or re-recording of some lectures after technical glitches. We have learned that developing these courses with two faculty members takes longer than when we work alone in our own disciplines and must plan for that. It is important, however, to note that this process has paved the way for other faculty teams to develop courses together, and at least one additional course has launched using this model, one that was widely deemed overly difficult or even impossible.

Getting us both (fairly) assigned to the teaching of this course caused difficulties even before the development began. We had to invent a way to designate the qualifications needed by each of the two faculty to ensure a sustainable support for courses that inherently require faculty from two distinct metadisciplines. The approval of a mathematics instructor for a humanities course was questioned at every level, including the quality managers after the course had actually begun. One of us received no compensation or workload reassignment for the first offering, though an evenly split stipend for teaching the next offering "above contract" was arranged by the end of the academic year. We need to go a step farther to get these halves worked into regular contracting before this becomes sustainable for the additional courses we are planning. Team teaching often involves some workload negotiation with Chairs and Deans, so it is best to be prepared with a clear plan of work that will satisfy administrators.

The students may have loved our "Gemini" concept in discussions, but we did have to keep a close eye on keeping the workload balanced between us. We each felt that we spent about the same amount of time in discussions as if we were teaching alone. Rather than each of us teaching half of a course, as it appears on paper, we felt as if the workload was a full course for each. Of course, this issue may dissipate in future offerings as we become more familiar with the pace of the class and more adept at dividing course responsibilities.

6.2. Arranging Synchronous Aspects of the Class

Despite, or perhaps because of, our university's prominence in the area of online education, we are always looking for ways to increase student and instructor interaction. One particular proposed solution has been the careful addition of synchronous elements to our courses. Given that our students live in multiple states, countries and even continents, this can be a difficult undertaking.

In this course, we determined that a "Bring Your Own Popcorn" viewing of a film would be a low-stakes way to create some sense of community. The week before discussing *Hidden Figures*, a survey was taken of what evening would most likely attract many students. We also asked about a weekend viewing for the sake of students outside North American time zones. There was no clear consensus on weekday availability nor a lot of interest for a weekend viewing. We advertised a Tuesday evening that had only two attendees and a Saturday morning with no attendees. It was disappointing for us, but we will try again since those two attendees were quite vocal in the discussion and final reflections about how much they appreciated the live interaction with instructors, wishing that more classmates had attended.

Our original plan was to also have a synchronous "fair" for the trailers in the final week of the course. Ideally, there would be a way to invite viewers from outside the course. The technicalities were a bit overwhelming and we settled for a complete/incomplete assignment for posting the trailer in a discussion for classmates to view and comment. It was no surprise that about half of the class posted theirs and never returned to engage with others, not even to read the responses to their own trailer that the other half of students posted. Just as the team teaching within contract needs further discussion with administration, this area still needs some work with academic technology to reach our initial expectations.

7. Conclusions and Looking Ahead

Despite these small setbacks, many of which would accompany any first-time course offering, the pilot offering of the class was an overwhelming success. In its second (March 2020), the class size ballooned to 29 students, with Scheduling asking us to increase future sections. One student commented that this course "should be *the* humanities requirement" at our STEM-focused university.

The success of HUMN 333 has prompted the College of Arts and Sciences to include Humanistic STEM as one of its strategic initiatives. As one of six areas of focus in the College, H-STEM now enjoys administrative support, including resources to assist us with disseminating the idea in multiple venues and to diverse audiences for the new academic year. We have given presentations about HUMN 333 and Humanistic STEM at the Joint Mathematics Meetings, the AAC&U Transforming STEM Education conference, and the National Numeracy Network. The Northeast Modern Language Association annual conference was our first humanities-focused audience, and we presented a 90-minute workshop on integrating H-STEM into a variety of institutional contexts — from infusions into existing courses, to creating new courses, to proposing minors and other programs.

We have received institutional support for additional courses, including a class on the history of communication technologies, an introduction to digital humanities, a class in storytelling with data, and a course focused on math and sciences in visual arts. In our October 2020 term, we introduced the first course in a six-hour math series called Learning to Reason. These courses will include topics such as probability, statistics, data science, proportional reasoning, geometry, trigonometry, financial literacy, and an introduction to calculus. Both will infuse history, culture, philosophy and ethics across all of these topics and include creative expression in at least one area.

Finally, we plan to create a virtual Humanistic STEM Center which will provide a home to facilitate collaboration among those who are interested in adopting H-STEM perspectives and projects at their own institutions. The H-STEM center will initially be a repository for diverse curriculum materials from a variety of educational contexts. Under the umbrella of the center, project leadership will seek out partner institutions to form a consortium which will run a series of workshops to assist other institutions in devel-

oping their own H-STEM initiatives — from single-course interventions, to individual courses, to complete programs. Until the H-STEM center is fully functional, we encourage interested readers to contact the authors directly with materials you want to share or what you might be looking for. We would also like to hear from potential partners.

This implementation process and resulting minor and center will provide a new way for students and faculty to encounter both meta-disciplines to reinforce their relevance. It will also offer universities a way to dispel the age-old perception that there is an adversarial relationship between the humanities and the more "pragmatic," technical skill-based STEM disciplines. Finally, the Virtual Humanistic STEM Center both allows a broad range of faculty to contribute their own course descriptions and syllabi to assist others with their course development and provides an opportunity for researchers in this area to easily find potential collaborators and share ideas, moving Humanistic STEM beyond ERAU into the larger academic arena.

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