# SENATE COMMITTEE ON CURRICULAR AFFAIRS

## COURSE SUBMISSION AND CONSULTATION FORM

***Principal Faculty Member(s) Proposing Course***

| Name | User ID | College | Department |
|---|---|---|---|
| JANE CAMILLA CHARLTON | jcc12 | Science (SC) | Not Available |
| Nahks Tr'Ehnl | jds255 | Science (SC) | Not Available |

**Academic Home:** Science (SC)

**Type of Proposal:** ☒ Add ☐ Change ☐ Drop

**Course Designation**

**(ASTRO 7N) The Artistic Universe**

## Course Information

**Cross-Listed Courses:**

**Prerequisites:**

**Corequisites:**

**Concurrents:**

**Recommended Preparations:**

| | |
|---|---|
| **Abbreviated Title:** | Artistic Universe |
| **Discipline:** | General Education |
| **Course Listing:** | Inter-Domain |

### Special categories for Undergraduate (001-499) courses

**Foundations**

☐ **Writing/Speaking (GWS)**

☐ **Quantification (GQ)**

**Knowledge Domains**

☐ **Health & Wellness (GHW)**

☒ **Natural Sciences (GN)**

☒ **Arts (GA)**

☐ **Humanities (GH)**

☐ **Social and Behavioral Sciences (GS)**

**Additional Designations**

☐ **Bachelor of Arts**

☐ **International Cultures (IL)**

☐ **United States Cultures (US)**

☐ **Honors Course**

☐ **Common course number - x94, x95, x96, x97, x99**

☐ **Writing Across the Curriculum**

**First-Year Engagement Program**

☐ **First-Year Seminar**

**Miscellaneous**

☐ **Common Course**

**GE Learning Objectives**

☐ **GenEd Learning Objective: Effective Communication**
☒ **GenEd Learning Objective: Creative Thinking**
☒ **GenEd Learning Objective: Crit & Analytical Think**
☐ **GenEd Learning Objective: Global Learning**
☒ **GenEd Learning Objective: Integrative Thinking**
☐ **GenEd Learning Objective: Key Literacies**
☐ **GenEd Learning Objective: Soc Resp & Ethic Reason**

### Bulletin Listing

| | |
|---|---|
| **Minimum Credits:** | 3 |
| **Maximum Credits:** | 3 |
| **Repeatable:** | NO |
| **Department with Curricular Responsibility:** | Astronomy And Astrophysics (UPSC_ASTRO) |
| **Effective Semester:** | FA 2018 |
| **Travel Component:** | NO |

## Course Outline

**A brief outline or overview of the course content:**
This course immerses students in the beauty and intricacy of the universe, and helps them to experience it on a personal level. All of the science content will be presented as students explore an astronomy-themed video game, in which their personalized avatars will walk on new planetary landscapes, navigate from star to star, and reconstruct the history of the universe by combining fundamental particles. The vastness of the universe and the emptiness of space is but one major philosophical theme presented, which impacts considerations of, for example, how many extraterrestrial civilizations could exist and how far separated we may be from them in time and space. To both demonstrate understanding of and develop a personal connection to the subject, students will create several art projects, including: a photo-journal for both inspiration and for building a body of references for later illustrations; a design of their own mini-game setting using tools created with the Unity 3D game engine; depicting an extrasolar planetary system; and constructing an aesthetically-pleasing and scientifically-informed/informative color image of a galaxy using real data.
The course's four primary units and the associated topics and art projects are outlined, here:
Unit 1:
Astronomy: Basic Astronomy and the Nighttime Sky — topics: basics of motion & gravity; seasons; phases of the Moon & eclipses; the night sky & constellations; properties of light, spectroscopy; telescopes; differences in everyday experiences, environmental conditions and geological forms, if one were living on another planet (Mars).
Art: Astronomical Art — topics: a brief history of exchange between arts and sciences (especially between visual arts and astronomy); sharing of ideas, inspirations.
Project: Create a short photo-journal of your own, with photos of astronomical objects or landscapes with relevance to planetary sciences in general (e.g., forms like rocks, mountains or craters, minerals, geologic processes, etc. — objects that could serve as terrestrial analogues to scenes of other planets, moons, etc.). Consider in an accompanying statement the limits of what you can experience of astronomy on a day-to- day basis, versus what you learn in the first unit about light, telescopes, motions and changes in the sky over time.
Unit 2:
Astronomy: The Solar System — topics: properties of the planets in our Solar System, including the Earth and its Moon, as well as major moons of other planets; laws of planetary motion; formation of the Solar System.
Art: Science Literacy, Speculation, and Artistic License — topics: importance of accuracy in illustration for educational purposes; speculative space art and visions of humans in space; trade-offs between creating depictions that are accurate versus that which can be visually, personally compelling.
Project: Create a planetary surface with realistic properties and set up a vehicle to explore it within a game setting (using a toolset, provided, based in the Unity game engine). Discuss the properties of the planet such as density, chemical composition, mass, radius, surface gravity, and atmosphere — and how these properties affect the virtual experience of "being there."
Unit 3:
Astronomy: Stars — topics: The Sun & properties of stars (how they work, mass, luminosity, temperature, color); stellar birth and death; white dwarfs, neutron stars, black holes; extrasolar planets and astrobiology.
Art: From Abstract Data to Visualization — topics: basics of where data come from, how it looks in raw form; interpreting data to visualize physical systems and processes; extrapolate possible extrasolar environments by comparing/combining new data with existing knowledge.
Project: Based on information delivered through NASA's "Eyes on Exoplanets" tool, depict a chosen extrasolar planetary system using chosen media, and describe its properties and any potential habitability of its planets.
Unit 4:
Astronomy: Galaxies and Cosmology — topics: Structure and composition of the Milky Way Galaxy, including star clusters, nebulae, and stellar remnants; different types and sizes of galaxies; galaxy evolution; dark matter & dark energy; the Big Bang & history of the universe.
Art: What We Can See Versus What We Are Looking For — topics: light beyond human vision; astronomy as time travel, and visualizing changes over time at multiple scales throughout the universe; assembling a human-readable multi-wavelength image.
Project: Construct two full-color images by combining three grayscale source images and assigning, to each of the latter, one of the primary color channels (red, green, blue). First: use three different images of the student's choice; the image will be titled, and

supplemented by a statement explaining the composition or motivation behind the selections, and the unifying theme. Second: using real Hubble Space Telescope and other observational data, combine images taken in different color filters to depict a galaxy that conveys the different ages of the stellar populations in different regions, with emphasis on maintaining visual clarity and remaining aesthetically pleasing. This replicates the process by which images such as the Hubble Space Telescope's "Hubble Heritage" images were created.

**A listing of the major topics to be covered with an approximate length of time allotted for their discussion:**
Basic Astronomy and the Nighttime Sky / Astronomical Art — 3 weeks
Art Project 1 — 1 week
The Solar System / Science Literacy, Speculation, and Artistic License — 3 weeks
Art Project 2 — 1 week
Stars / From Abstract Data to Visualization — 3 weeks
Art Project 3 — 1 week
Galaxies and Cosmology / What We Can See Versus What We Are Looking For — 2 weeks
Art Project 4: 1 week

**Course Description:**
ASTRO 7N (GA/GN) is both an introductory course in astronomy for non-science majors and a creative space for those with science backgrounds interested in visual arts; it provides students the opportunity to demonstrate understanding and develop a personal connection to the subject by designing four art projects. Students will learn the broad concepts of astronomy by playing an immersive video game, which allows them to 1) explore seasons, phases of the Moon, light, gravity, and telescopes from a virtual colony on Mars; 2) fly from planet to planet in the Solar System and learn about their properties and formation; 3) visit the Sun and other stars, learn how they produce energy, and about their life cycles; 4) fly through the cosmos and construct their own universe, particle by particle. Students will also learn about the relationships and exchanges between arts and sciences, and explore inspiration and perspective on these topics by designing themed art projects using traditional and digital media. These projects include assembling a photo- journal of astronomically-relevant subjects, constructing their own video-game-like scene, interpreting data to inform a plausible depiction of an alien world, and producing three- color images using methods like those employed by astronomers to compose and display Hubble Space Telescope images.

**The name(s) of the faculty member(s) responsible for the development of the course:**

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## Course Justification

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**Instructional, Educational, and Course Objectives:**
**This section should define what the student is expected to learn and what skills the student will develop.**
To engage students in an investigation of astronomy in a more active way so that they will achieve a deeper understanding of concepts. To convey the idea that astronomy has relevance to many people, through appreciation of the beauty of astronomical objects and perspective of origins. To guide students in creating and analyzing astronomical images and landscapes, using a creative and scientifically-accurate approach.
After taking this course, students should be able to:
1. Describe the position of the Earth in the context of the overall Universe — i.e., in an orbit around the Sun, which is one of many stars traveling around the center of the Milky Way galaxy, that is one of billions and billions of galaxies in the Universe; to understand the scales of objects in space; to understand that there are countless other stellar planetary systems; use observational data and theory to inspire speculative illustrations of being in other locations in the Universe;
2. Explain how the Sun shines, and why stars come in different colors; to apply knowledge of what color represents (temperature, energy, wavelength); to produce three- color images of astronomical objects that highlight scientifically-interesting regions/ concepts, and are aesthetically pleasing;
3. Give a brief history of the universe from the beginning of the Big Bang expansion to the formation of galaxies, stars, and planets; recall examples from history of artistic attempts to depict astronomical objects and scenes both before and after direct observations are made, by human space missions and the like;
4. Describe the basic properties of the planets in the Solar System and major moons; depict an extrasolar-planetary system based on real data; to gain a window into the basics of how a video game is designed and produced.

**Evaluation Methods:**

**Include a statement that explains how the achievement of the educational objective identified above will be assessed. The procedures for determining students' grades should be specifically identified.**
Student achievement will be assessed by a combination of successful completion of the video game, art projects and their accompanying statements, and exams.
The breakdown will be approximately:
Art projects and descriptions -- 4 projects worth 10 % each, for a total of 40 % of the overall grade;
Completion of the video game with included low-stakes quizzes -- 4 units worth 10 % each, for a total of 40 %;
Midterm exams -- 2 multiple-choice exams on astronomy concepts, worth 10 % each, for a total of 20%.
The specific objectives listed above will be assessed as follows:
1. The video game that the students will play at points involves in part flying a spaceship from planet to planet within our Solar System, from star to star in our galaxy, and from galaxy to galaxy. Observing this and the length of time it takes to fly gives students perspective on the vast sizes and large empty spaces involved. These concepts will be examined in quiz questions throughout the game and by carefully designed questions on midterms.
2. One of the student projects will involve composing three-channel color images and describing how their choices are informed by astronomy concepts. For example, regions of a galaxy with recent star formation would be blue because of the domination of high-mass blue stars that die out on short timescales, while old regions of a galaxy would be red. Also, the video game leads students to constructing a "Hertzsprung-Russell diagram" by collecting measured stars' properties and plotting luminosity versus temperature. Test questions require students to interpret trends on this diagram.
3. For the history of the Universe, the video game contains sub-games allowing students to create an excess of matter over matter via particle annihilation, to build protons and neutrons using up and down quarks, to build helium by putting protons and neutrons together, etc., so that they are in effect reconstructing the history of the universe. They will be tested to be sure they understand the events and their order. Additional materials will present a timeline of artists, movements, and examples of astronomy-themed art — of varied realism or plausibility based on astronomy knowledge in the artists' times.
4. Students travel from planet to planet, constructing a summary table of planet properties, and answer questions that interpret this table. In one of the art projects students will use Unity (game engine, www.unity3d.com) in a guided manner to put different visual elements together to form a planetary landscape -- design a small colony and/or vehicle, and set that in motion in their own mini-game.

**Relationship/Linkage of Course to Other Courses:**
**This statement should relate the course to existing or proposed new courses. It should provide a rationale for the level of instruction, for any prerequisites that may be specified, or for the course's role as a prerequisite for other courses.**
This course is an inter-domain GN/GA general education course. It combines introductory astronomy for non-science majors with a variety of explorations through visual arts and interactive multimedia. The astronomy topics are the same (and presented at the same level) as those covered in Astro 1 and Astro 10. They also overlap with Astro 5 and Astro 6, which cover the same topics (as Astro 1, Astro 10, and this proposed Astro 7) in more depth over the course of two semesters. As such, students may only receive credit for one of the classes (Astro 1, 5, 6, 7, and 10). Students may take the 1-credit laboratory course, Astro 11, concurrently or following Astro 7, since the lab activities in that class do not overlap substantially with the Astro 7 curriculum.
Since the art projects in this class are especially related to astronomical images and landscapes, there should be little overlap with ART courses. Clearly, students who have taken those classes could apply techniques they have learned to the assigned projects. In Astro 7, students will learn some image-processing and video-game design concepts that would relate to visual arts classes they may take or may have taken. In other presentations and projects, students will review art history specific to "astronomical art."

**Relationship of Course to Major, Option, Minor, or General Education:**
**This statement should explain how the course will contribute to the major, option, or minor and indicate how it may function as a service course for other departments.**
This course is a General Education course and also an inter-domain course with GN/GA designation. It is not specifically required for any major or minor. However, the Planetary Science and Astronomy major requires an introductory astronomy class, and we propose that this be added to the list presently given; i.e.,
"Select 3 credits from ASTRO 1 GN(3), ASTRO 5 GN(3), ASTRO 6 GN(3), ASTRO 291 GN(3) (Sem: 1-4)"
To this list we propose to add "ASTRO 7N GN/GA(3)"

**A description of any special facilities:**
This class is entirely online, so students must either use a computer lab on campus, or a personal laptop or desktop computer. We provide technical support in case of any difficulties they might have. On University Park campus, testing will require a computer testing facility (such as the Pollock Testing Center) for 2 midterm exams.

**Frequency of Offering and Enrollment:**
This course would be offered each Fall semester at University Park campus with expected enrollment of 500 students and no enrollment cap. Grading is automated and/or through peer grading (with a rubric given to guide these evaluations), so large numbers are entirely feasible. It would also be offered each Fall through World Campus with expected enrollments of 200 students and no enrollment cap. Depending on the level of interest the course could be offered in the Spring as well.

## Alignment with General Education Objectives

☐ **EFFECTIVE COMMUNICATION – the ability to exchange information and ideas in oral, written, and visual form in ways that allow for informed and persuasive discourse that builds trust and respect among those engaged in that exchange, and helps create environments where creative ideas and problem-solving flourish.**

☐ **KEY LITERACIES – the ability to identify, interpret, create, communicate and compute using materials in a variety of media and contexts. Literacy acquired in multiple areas, such as textual, quantitative, information/technology, health, intercultural, historical, aesthetic, linguistic (world languages), and scientific, enables individuals to achieve their goals, to develop their knowledge and potential, to lead healthy and productive lives, and to participate fully in their community and wider society.**

☒ **CRITICAL AND ANALYTICAL THINKING – the habit of mind characterized by comprehensive exploration of issues, ideas, artifacts, and events before accepting or formulating a conclusion. It is the intellectually disciplined process of**

**conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.**

☒ **INTEGRATIVE THINKING – the ability to synthesize knowledge across multiple domains, modes of inquiry, historical periods, and perspectives, as well as the ability to identify linkages between existing knowledge and new information. Individuals who engage in integrative thinking are able to transfer knowledge within and beyond their current contexts.**

☒ **CREATIVE THINKING – the capacity to synthesize existing ideas, images, or expertise in original ways and the experience of performing, making, thinking, or acting in an imaginative way that may be characterized by innovation, divergent thinking, and intellectual risk taking.**

☐ **GLOBAL LEARNING – the intellectually disciplined abilities to analyze similarities and differences among cultures; evaluate natural, physical, social, cultural, historical, and economic legacies and hierarchies; and engage as community members and leaders who will continue to deal with the intricacies of an ever-changing world. Individuals should acquire the ability to analyze power; identify and critique interdependent global, regional, and local cultures and systems; and evaluate the implications for people's lives.**

☐ **SOCIAL RESPONSIBILITY AND ETHICAL REASONING – the ability to assess one's own values within the social context of problems, recognize ethical issues in a variety of settings, describe how different perspectives might be applied to ethical dilemmas, and consider the ramifications of alternative actions. Individuals should acquire the self-- knowledge and leadership skills needed to play a role in creating and maintaining healthy, civil, safe, and thriving communities.**

**What component(s) of the course will help students acheive the General Education Learning Objectives covered in the course? Provide evidence that students in the course have adequate opportunities to achieve the identified learning objectives.**

Critical and Analytical Thinking:

There are many sub-games in the video game that the students will be playing that require collection of data and testing inferences in order to find a viable theory to explain a physical phenomenon. For example, students are asked to explain why most of the closest stars are red, while the brightest stars in the sky tend to be mostly blue. They visit stars and use their observed spectra to determine the temperatures of the stars (which correspond to color). Then they make a plot of luminosity versus temperature and discover that the blue stars are more luminous, and that the nearby stars tend to be of lower luminosity. They are guided through a series of questions that lead them to the conclusion that although most stars are low mass and red, the very most luminous stars are blue, and we can see those to greater distances.

Another example is where students are asked to determine what the neutron-to-proton ratio should be in order to have 25% of the mass of the early universe converted to helium. They do this by experiment, putting particles together, assuming different neutron to proton ratios, until they get it right. There are at least twenty such critical and analytical thinking activities in the video game.

Consideration of compositional elements (form, balance, clarity, etc.) involved in creating art, explanations for decisions expressed through writing the accompanying statements for these works, and applying critical senses in evaluating classmates' art project submissions, will also require this type of thinking.

Integrative Thinking:

The connections between art and astronomy will be forged by the students with just this type of thinking. For example, students will take several images obtained by the Hubble Space Telescope with different color filters, choose colors representing each, and superimpose these images to present a visually-appealing and informative work of art. This activity will require students to draw upon the information about the different colors of stars from the Hertzsprung-Russell graph, and the information about the locations of the different types of stars in a galaxy. They will need to choose colors for their images based on this information.

Another of the art projects involves looking at the NASA's "Eyes on Exoplanets" application to find a specific star that is known to have extrasolar planets. The students will use the information given in NASA's Eyes to produce a work of art depicting a scene in that planetary system, based on distances, temperatures, and masses of the planets. Students will pay attention to the composition of the piece, the aesthetic appeal, as well as the scientific accuracy.

Other opportunities for integrative thinking arise in the context of the video game's challenges. For example, students learn about the origin of absorption lines from different chemical elements in the first unit of the course, and then apply it to determine the temperatures of stars in the third unit. They explore the concept of gravity in the context of experimenting to determine the formula for surface gravity in the first unit, then apply it again to determine the mass of Jupiter from the motions of its moons in the second unit, and then again apply it to derive the amount of dark matter in a galaxy in the final unit of the course. Connecting to the earlier explorations makes it easier for the students to grasp the later, more abstract concepts.

Creative Thinking:

Both science and art are areas rich with potential for creative thinking. The activities for this class are carefully designed to encourage creative freedom, incorporating knowledge of astronomy gained from our interactive game. In one art project, students will choose three images, assign each one a color channel, and then superimpose them. They will title this work, and explain the motivation for each component's selection and the unifying theme. Their project will be reviewed by their peers, using an established rubric, and students can gain perspectives and inspirations by examining the work of their peers. Other projects will challenge students to create alien world landscapes (one a scene similar to some in the video game — with many choices of colors, shapes, and textures — the other a scene based on real data but still with a range of unknown quantities, thus ripe for speculation and artistic license); but again, these are informed and motivated by the science they have learned. Again, their creations will be shared with and evaluated by a panel of their peers.

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**How will students be assessed to determine their attainment of the Learning Objective(s) of General Education covered in this course? This assessment must be included as a portion of the student's overall performance in this course.**

Completing the video game and the embedded quizzes, worth 10 % of the course grade for each of four units, will require varied and significant Critical and Analytical Thinking. Since key concepts, such as gravity and radiation, recur multiple times over the course in different contexts, Integrative Thinking is also required.

The two midterm exams focus on the astronomy concepts in the course, but emphasize questions that test the depth of students' mental pictures of the universe. Examples are the question “How many stars are there in the Solar System?”, or “Order the following, from largest to smallest: galaxy, Sun, Earth, Solar System, a nebula, Universe." These tests are worth a total of 20 % of the course grade. As in completing the video game's lesson modules, successful performance will require Critical and Analytical Thinking as well as Integrative Thinking.

The four art projects in the course, each worth 10 % of the course grade, will require a significant amount of Creative Thinking. Students will have a lot of creative freedom in these varied projects, which will also require synthesis of the astronomy concepts with artistic sensibilities and techniques. In writing the projects' accompanying captions or statements Integrative Thinking, and to a lesser degree Critical and Analytical Thinking, will be exercised in explaining the creative choices that were made.

## General Education Domain Criteria

**General Education Designation:** Inter-Domain

### GA Criteria

☐ **Explain the methods of inquiry in arts fields and describe how the contributions of these fields complement inquiry in other areas**

☒ **Demonstrate an expanded knowledge and comprehension of the role that the arts play in various aspects of human endeavor**

☒ **Demonstrate competence in the creation of works of art and design**

☒ **Demonstrate competence in analysis, critical thinking and interpretive reasoning through the exploration of creative works**

☐ **Identify and explain the aesthetic, historic, social, and cultural significance of important works of art and critically assess creative works, their own or others', through evaluative processes of analysis and interpretation**

**What components of the course will help students acheive the domain criteria selected above?**

Demonstrate an expanded knowledge and comprehension of the role that the arts play in various aspects of human endeavor:
The course will include presentations on the history of astronomical subjects represented in visual arts — from ancient works, through modern realism and similar movements, and about contemporary "space artists" such as the International Association of Astronomical Artists (http://iaaa.org). A video interview with a specialist in astronomy image production (with advanced training in art and astronomy), Prof. Jayanne English of the University of Manitoba, will be included in the introduction to one of the art activities. Prof. English will describe how the choices of colors and intensities for astronomical images can be important to highlight regions of the image that are important to drawing scientific conclusions.
Astronomy can be done more effectively if scientists can visualize things differently. This is especially important in constructing theories of star formation, addressing the question of whether stars form in isolation or in groups, and exploring triggered star formation that propagates through a galaxy. Furthermore, many important findings are based on X-ray, radio, gamma-ray, infra-red, and ultraviolet observations, and we cannot see those types of radiation with our eyes. Artistic sensibilities are very important to produce images that allow interpretation of the objects — e.g., without being so busy as to disguise important conclusions.
Sciences like astronomy and art provide no shortages of inspiration for each other; speculative and science-fiction art (paintings, animation, scenes in popular television programs and movies, etc.) depicting human exploration of space, for instance, can lead to targeted research and advances in the sciences. Students will be able to explore these aspects in creating their own astronomy art.
Demonstrate competence in the creation of works of art and design:
Four art/design projects will be completed by each student, with themes related to the astronomical content of the course. One will involve image processing, particularly emphasizing color composition. (Separate but equivalent activities will be available for students who are color-vision impaired.) Another will involve a plausible depiction of an extrasolar planetary system using media of their choice. Finally, there will be an activity to design a mini-video game scene, of an at-least semi-realistic planetary surface.
Tutorials and engaging information will be provided to help students gain skills to combine with their imaginations. For example, in the interview with Prof. Jayanne English of the University of Manitoba (who worked for the "Hubble Heritage" project to produce Hubble images for the public) she will give students new perspectives on what makes images appealing. One concept that Prof. English will explain is how orientation of an image (say a galaxy group) is crucial to whether it is appealing to the public. It is important to draw the eye in and keep the viewer interested and engaged with the image, and the orientation can significantly affect how long someone will look at it. Students will describe how they made these decisions in making their own creations and their peers will consider this when grading the projects.
Demonstrate competence in analysis, critical thinking and interpretive reasoning through the exploration of creative works:
Students will have the opportunity to analyze the work of their peers in order to grade it according to specific rubrics. For example, the students will be required to include a description of how color choices for the three-color-channel images project were made in order to both appeal aesthetically, and to highlight and facilitate transmission of information of a specific concept. As mentioned above, the colors of stars highlight their ages. Also, colors can be assigned to images generated originally by captured radiation not visible to the human eye.
Students will learn that the pictures they see of space are not just a simple snapshot taken by a telescope nor necessarily representative of what a human eye would see "if you were there," in-person. They will also gain understanding of the physical processes that underlie certain "raw" data or graphs, and how this can lead to informed illustrations of various systems. The beauty of space is really only fully revealed with the help of the human brain to synthesize many types of data and related images and create an accurate interpretation.

### GN Criteria

☐ **Explain the methods of inquiry in the natural science fields and describe how the contributions of these fields complement inquiry in other areas**

☒ **Construct evidence-based explanations of natural phenomena**

☒ **Demonstrate informed understandings of scientific claims and their applications**

☐ **Evaluate the quality of the data, methods, and inferences used to generate scientific knowledge**

☒ **Identify societal or philosophical implications of discoveries in the natural sciences, as well as their potential to address contemporary problems**

**What components of the course will help students acheive the domain criteria selected above?**

Construct evidence-based explanations of natural phenomena:
There are numerous examples of activities that require students to construct evidence- based explanations of astronomical phenomena in the video game. We will give three examples, here.
1) Students are asked to collect data on the temperatures of the planets in our Solar System. They are also asked to calculate the semi-major axis of the orbit of each planet, using its orbital period and applying Kepler's Third Law of planetary motions. Later, the students plot the temperature versus semi-major axis. They will see a general trend, but Venus is a notable exception; they are able to reason out that the temperature is higher for Venus because of the strong greenhouse effect of its atmosphere, which has already been a significant issue in the story-line for the game.
2) Students learn to reason out what time the Moon rises and sets when it is in a given phase (and many other aspects of Moon phases) by manipulating the position of the Moon relative to the Earth and Sun in a game activity.
3) Students measure the distances and redshifts of galaxies by measuring images and spectra, and construct a plot of velocity versus distance — such as was used to determine that the Universe is expanding.
Demonstrate informed understandings of scientific claims and their applications:
Again, there are dozens of examples in the video game of astronomical theories that are explained and applied. For example: students learn about how absorption and emission lines in spectra are produced, by manipulating the electrons in atoms of different chemical elements to show how individual lines are produced. They then use spectral analysis later in the course in order to measure the temperatures of stars, and again in measuring the redshifted wavelengths of key spectral features to determine the velocity of recession of galaxies.
As another example, by observing the Hertzsprung-Russell diagram for globular star clusters, students will see how astronomers learned that blue stars have shorter lifetimes than red stars. They will apply this to create realistic images of galaxies, to highlight regions of different ages, in one of their art projects.
Identify societal or philosophical implications of discoveries in the natural sciences, as well as their potential to address contemporary problems:
Students will be engaged as characters in a science fiction story that is part of the video game. In the story, a student's avatar is first faced with how life would certainly differ, in some ways obvious and in other ways subtly, for humans living in a colony on another world. The effect this could have on one's perspective of Earth, and of the common origins and experiences of its population — reinforced by the sight of Earth from afar — is profound. Later, the story's main characters face a situation where they can play a mini- game to rescue speculative lifeforms in Jupiter's atmosphere from destruction (by a diamond mining operation from a competing team).
As the storyline builds, the characters discover that their "teacher" is in fact a part of a collective consciousness that came from a parallel universe at the origin of our universe. It is amazing to ponder the question of how and why we and our universe are here — of the myriad laws of physics and sequence of events that led to the present — and students are encouraged to think about how this affects them. Even appreciation of the sheer volume of the universe, and of the place and scale of humanity within it, is a worthwhile basic concept.

## Integrative Studies

**Explain how the intellectual frameworks And methodologies of the two Knowledge Domains will be explicitly addressed in the course and practiced by the students.**

The students will learn about the concepts of astronomy and the scientific method through many activities in the video game, in which they will be participants. They will examine diagrams and images, make and interpret graphs, and experiment to test hypotheses while playing the game. They will also be tested on this content.
Students will learn about analysis and composition of astronomical images through video presentations from those practicing in the field, and through game-like tutorials. They will also explore what may and may not be not effective in the field of scientific figures and illustrations, through careful analysis of the art projects of their peers which they will be grading.

**Demonstrate that each Of the two domains will receive approximately equal attention, providing evidence from course topics, assignments, or other course components, and that students will integrate material from both domains.**

Students will receive 40 % of the course credit for completing video game material, 40 % for art projects, and 20 % for multiple-choice exams. The video game does focus on the astronomy concepts, but it does also teach about the physical bases of light and color, and of course presents many astronomical images (including artists' conceptions) that the students will be analyzing.
In addition to the science content, students will gain information on the history of relationships between astronomy and visual arts — and how through transmission of knowledge, or inspiration, the two fields can serve each other constructively. Considerations in creating realistic "astronomical art" include the geometrical configurations of the system in question (e.g., as influences the apparent sizes and/or phases of objects), lighting (from central elements in the scene, and/or reflected from something out of the scene; directions, colors, intensities; amounts of transparency), plausible geological or astrophysical processes involved in creating various forms (e.g., gravitationally or "wind" sculpted gaseous regions; tectonically- or impact-generated landforms; relative ages, weathering, etc.). In completing the art projects, students will receive instruction that further melds the two areas together with example works and suggestions for additional source material. Appreciation of beauty in the natural world is also a general theme throughout the course.

**Briefly explain the staffing plan. Given that each Inter-Domain course is approved for two Knowledge Domains, it will be taught by an instructor (or instructional team) with appropriate expertise in both domains.**

This course is delivered purely online and is designed by:
Jane Charlton, a Professor in the Department of Astronomy and Astrophysics. Prof. Charlton has been the project lead (especially curriculum and story design) on two highly- popular online Astro 1 courses developed over the last decade.
Nahks Tr'Ehnl, a Multimedia Specialist in the Department of Astronomy and Astrophysics. Nahks is an alumnus of Penn State with degrees in both Art (BA) and Astronomy & Astrophysics (BS). He is also an Artist Member of the International Association of Astronomical Artists, with experience in illustration and graphic design in support of astronomy research, education, and public outreach. Nahks has designed most of the visual assets and interfaces for the current two online versions of Astro 1 at Penn State.
Tim Schneider, a Programmer/Analyst (video game developer) in the Department of Astronomy and Astrophysics. He holds a BS degree in Information Sciences & Technology from Penn State, and has expertise in tutorial systems for video games and education.

We have consulted with colleagues who specialize in producing astronomy images for the general public at the Space Telescope Science Institute, and will include information on that topic, as well as a personal interview with one, Dr. Jayanne English, who combines the fields of art and astronomy in her work as a Professor at the University of Manitoba. We have also solicited feedback on our course concepts from members of the International Association of Astronomical Artists, some of whom are also university faculty in physical sciences as well as accomplished lifetime artists with work featured in major publications, motion pictures, and television; many IAAA members have also given presentations or contributed to books on the interface between arts and astronomy (or sciences in general), or have organized workshops on creating astronomical art.
In the immediate future (the next few Fall semesters, starting in Fall 2018) the plan is for Jane Charlton and Nahks Tr'Ehnl to administer the online course, with assistance from Tim Schneider. Any faculty member in astronomy could clearly fulfill this role, since prepared materials that the students use are very clear; however, Dr. Chris Palma, Dr. Julia Kregenow, and Dr. Ana Matković are among others in the Astronomy Department with significant previous experience teaching large, online courses.

**Describe the assessments that will be used to determine students' ability to apply integrative thinking.**

The four art projects will require extensive integrative thinking, as will the peer grading of these assignments. For example: students will choose a set of images obtained using various wavelength filters through several space telescopes, and will decide what visible light primary color channels to assign to each one; then they will superimpose the images to produce an aesthetically-pleasing and scientifically-meaningful final image. They will clearly describe their motivation in making these choices in a short written explanation submitted alongside the two images in fulfillment of the overall project assignment. A rubric for evaluating the successful achievement of this project's objectives may include the following:
"Score 0, 1, or 2 for each criterion, below — 0 if the piece submitted failed to include or address the basic criterion, 1 if the piece met the requirement at only a partial or minimal level, 2 if the piece fully met or exceeded expectations; accompany each of these with a brief (sentence or two) justification for your selection.
"A: The work identifies an astronomical object, and the composer has obtained three different wavelengths' (or wavelength regions') images for that object." (for example: a combination of visible-light, infrared, and ultraviolet images of the Andromeda Galaxy).
"B: The completed work has successfully aligned and overlain the three source images (some positioning, rotation, and/or scaling adjustments were likely necessary) with each one assigned one of the red, green, and blue color channels (or, if other custom color channels were chosen, justification was provided).
"C: The combination produces an overall image that is clearly 'readable' in both its component colors and as the sum of them; this may mean areas of isolated single color and areas of blended colors, highlighting different regions of stellar activity and/or chemical composition.
"D: The resulting combined image is clear and aesthetically pleasing — considering object size and placement, exposure, balance, etc.
"E: The submission is accompanied by a brief (~ 1 page) description of the artist's chosen object. First, the object and the source (s) of component images are identified. From their understanding of stars and galaxies gained throughout this semester, the composer briefly details what some results of overlaying those images may be, as far as highlighting what processes are going on in the object(s) visible." (for example: which regions of the Andromeda Galaxy indicate presence or depletion of star-forming material; which regions are dominated by younger versus older stellar populations — and how can one tell, etc.)
Another example: for the design of a mini-video game scene, a student will consider the temperature, chemical composition, location in space, and size of the planet or moon in choosing the appearance of the avatar, planetary landscape type, presence of not of a human colony and/or a vehicle, and possible depiction or suggestion of extraterrestrial life. Peer grading will use a rubric that includes assessment of attention to scientific accuracy (or plausibility) as supported by the submitter's accompanying written explanation, as well as general playability (including functional considerations in world design, object placement, mobility, view control, etc.).

## Campuses That Have Offered ( ) Over The Past 4 Years

| semester | AB | AL | BK | BR | BW | CR | DS | ER | FE | GA | GV | HB | HN | HY | LV | MA | NK | PC | SH | SL | UP | WB | WC | WS | XC | XP | XS | YK |
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***UPLOADED DOCUMENTS FOLLOW:***

# Astro 7: The Artistic Universe, Fall 2018

*instructors*: Jane Charlton, Nahks Tr'Ehnl, Timothy Schneider

*course office*: 439 Davey Lab (at Penn State, University Park campus)

*mailing address*: 525 Davey Lab / University Park, PA 16802

*office phone*: 814-863-6040

*office hours*: (online, or by appointment)

*email*: l-astro7game@lists.psu.edu

## Course Information:

*credits*: 3

*class meeting times / location*: No class meetings — material is delivered online, through *Canvas*.

*course start date*: Monday, 20 August 2018

*required text*: None — all material is provided in the game, embedded art assignment demonstrations, and associated web links. You will download a standalone game program, using links provided in *Canvas*.

## General Education Learning Objectives:

☒ **CRITICAL AND ANALYTICAL THINKING – the habit of mind characterized by comprehensive exploration of issues, ideas, artifacts, and events before accepting or formulating a conclusion. It is the intellectually disciplined process of conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.**

☒ **INTEGRATIVE THINKING – the ability to synthesize knowledge across multiple domains, modes of inquiry, historical periods, and perspectives, as well as the ability to identify linkages between existing knowledge and new information. Individuals who engage in integrative thinking are able to transfer knowledge within and beyond their current contexts.**

**CREATIVE THINKING – the capacity to synthesize existing ideas, images, or expertise in original ways and the experience of performing, making, thinking, or acting in an imaginative way that may be characterized by innovation, divergent thinking, and intellectual risk taking.**

## Description:

This course immerses students in the beauty and intricacy of the universe, and helps them to experience it on a personal level. All of the science content will be presented as students explore an astronomy-themed video game, in which their personalized avatars will walk on new planetary landscapes, navigate from star to star, and reconstruct the history of the universe by combining fundamental particles. The vastness of the universe and the emptiness of space is but one major philosophical theme presented, which impacts considerations of, for example, how many extraterrestrial civilizations could exist and how far separated we may be from them in time and space. To both demonstrate understanding of and develop a personal connection to the subject, students will create several art projects, including: a photo-journal for both inspiration and for building a body of references for later illustrations; a design of their own mini-game setting using tools created with the Unity 3D game engine; depicting an extrasolar planetary system; and constructing an aesthetically-pleasing and scientifically-informed/ informative color image of a galaxy using real data.

The course's four primary units and the associated topics and art projects are outlined, here:

**Unit 1:**

**Astronomy: Basic Astronomy and the Nighttime Sky** — topics: basics of motion & gravity; seasons; phases of the Moon & eclipses; the night sky & constellations; properties of light, spectroscopy; telescopes; differences in everyday experiences, environmental conditions and geological forms, if one were living on another planet (Mars).

**Art: Astronomical Art** — topics: a brief history of exchange between arts and sciences (especially between visual arts and astronomy); sharing of ideas, inspirations.

**Project:** Create a short photo-journal of your own, with photos of astronomical objects or landscapes with relevance to planetary sciences in general (e.g., forms like rocks, mountains or craters, minerals, geologic processes, etc. — objects that could serve as terrestrial analogues to scenes of other planets, moons, etc.). Consider in an accompanying statement the limits of what you can experience of astronomy on a day-to- day basis, versus what you learn in the first unit about light, telescopes, motions and changes in the sky over time.

**Unit 2:**

**Astronomy: The Solar System** — topics: properties of the planets in our Solar System, including the Earth and its Moon, as well as major moons of other planets; laws of planetary motion; formation of the Solar System.

**Art: Science Literacy, Speculation, and Artistic License** — topics: importance of accuracy in illustration for educational purposes; speculative space art and visions of humans in space; trade-offs between creating depictions that are accurate versus that which can be visually, personally compelling.

**Project:** Create a planetary surface with realistic properties and set up a vehicle to explore it within a game setting (using a toolset, provided, based in the Unity game engine). Discuss the properties of the planet such as density, chemical composition, mass, radius, surface gravity, and atmosphere — and how these properties affect the virtual experience of "being there."

**Unit 3:**

**Astronomy: Stars** — topics: The Sun & properties of stars (how they work, mass, luminosity, temperature, color); stellar birth and death; white dwarfs, neutron stars, black holes; extrasolar planets and astrobiology.

**Art: From Abstract Data to Visualization** — topics: basics of where data come from, how it looks in raw form; interpreting data to visualize physical systems and processes; extrapolate possible extrasolar environments by comparing/combining new data with existing knowledge.

**Project:** Based on information delivered through NASA's "Eyes on Exoplanets" tool, depict a chosen extrasolar planetary system using chosen media, and describe its properties and any potential habitability of its planets.

**Unit 4:**

**Astronomy: Galaxies and Cosmology** — topics: Structure and composition of the Milky Way Galaxy, including star clusters, nebulae, and stellar remnants; different types and sizes of galaxies; galaxy evolution; dark matter & dark energy; the Big Bang & history of the universe.

**Art: What We Can See Versus What We Are Looking For** — topics: light beyond human vision; astronomy as time travel, and visualizing changes over time at multiple scales throughout the universe; assembling a human-readable multi-wavelength image.

**Project:** Construct two full-color images by combining three grayscale source images and assigning, to each of the latter, one of the primary color channels (red, green, blue). First: use three different images of the student's choice; the image will be titled, and supplemented by a statement explaining the composition or motivation behind the

selections, and the unifying theme. Second: using real Hubble Space Telescope and other observational data, combine images taken in different color filters to depict a galaxy that conveys the different ages of the stellar populations in different regions, with emphasis on maintaining visual clarity and remaining aesthetically pleasing. This replicates the process by which images such as the Hubble Space Telescope's "Hubble Heritage" images were created.

## Course Learning Objectives:

To engage students in an investigation of astronomy in a more active way so that they will achieve a deeper understanding of concepts. To convey the idea that astronomy has relevance to many people, through appreciation of the beauty of astronomical objects and perspective of origins. To guide students in creating and analyzing astronomical images and landscapes, using a creative and scientifically-accurate approach.

After taking this course, students should be able to:

1. Describe the position of the Earth in the context of the overall Universe — i.e., in an orbit around the Sun, which is one of many stars traveling around the center of the Milky Way galaxy, that is one of billions and billions of galaxies in the Universe; to understand the scales of objects in space; to understand that there are countless other stellar planetary systems; use observational data and theory to inspire speculative illustrations of being in other locations in the Universe;

2. Explain how the Sun shines, and why stars come in different colors; to apply knowledge of what color represents (temperature, energy, wavelength); to produce three- color images of astronomical objects that highlight scientifically-interesting regions/ concepts, and are aesthetically pleasing;

3. Give a brief history of the universe from the beginning of the Big Bang expansion to the formation of galaxies, stars, and planets; recall examples from history of artistic attempts to depict astronomical objects and scenes both before and after direct observations are made, by human space missions and the like;

4. Describe the basic properties of the planets in the Solar System and major moons; depict an extrasolar-planetary system based on real data; to gain a window into the basics of how a video game is designed and produced.

## Testing Schedule:

The two midterm tests will be given at Pollock eTesting Center on the University Park Campus. Scheduling emails will be sent out by the testing center a week before each exam so you can choose a time that works for you. The testing periods for University Park students will be:

- Test 1: Wednesday 10/10 – Thursday 10/11;
- Test 2: Tuesday 12/4-Wednesday 12/5;

For World Campus students the exams will be available on Canvas for longer periods encompassing those same dates.

There are individual deadlines for completing portions of the game, for completing art projects, and for peer grading art projects assigned to you. These due dates will be announced at the beginning of each of the four units, and are also noted in the *Canvas* modules.

**Requirements:**

- Complete all the parts of the four video game "Units" by their due dates. The Units are divided into 2-3 "Parts" each, and there will be intermediate deadlines for completing each Part.
- Complete four art projects.
- Submit peer grading for art projects of classmates.
- Complete pre- and post-course surveys.
- Take two mid-term Unit tests.

**Course Prerequisites:**

None.

**Grading Policy:**

Your overall grade — out of 100% — is calculated based on the following...

- 39% for completion of the video game (sum of all 4 Units' parts — or 9.75% for each Unit)
- 20% for two mid-term exams (10% for each one)
- 1% for completion of the two Astronomy Surveys (a pre- and post-course survey, 0.5% each)
- 36% for completion of the four art projects (9% for each one)

- 4% for submitting peer grading of each of the four art projects (1% for each one)

The **guaranteed** grading boundaries (*i.e.*, you will receive at least this grade if you have this final average) are: >93.0% A; >90.0% A-; >87.0% B+; >83.0% B; >80.0% B-; >77.0% C+; >70.0% C; >60.0% D.

**Academic Integrity Policy:**

The Department of Astronomy and Astrophysics adheres to the Eberly College of Science policy of Academic Integrity, in accordance with the University policy. The Department's detailed policy is to be found on our policy page, where details of procedures in case of suspected violations are provided, as is the full text of the department's policy.

**Examination Policy:**

There are two mid-term Tests, one on the material from Units 1 and 2, and another on the material from Units 3 and 4.

Tests will be given at the Pollock eTesting Center at the University Park campus. N*o notes or other references may be used, nor calculators or other aids* — you may however have blank scratch paper and a pencil handy to draw figures or work out some calculations, if needed. The scratch paper will be provided at the testing center, but you should bring your own pen/pencil. When the exam approaches you will receive more-detailed instructions, review materials, and a scheduling email from Pollock one week before.

(For World Campus students similar instructions will apply for Canvas exams.)

**Disability Policy:**

This version of our Astro 7 online course may not be fully accessible to students with certain types of disabilities due to the video-game features. However, we do offer equivalent materials online that are story-based, rather than a game, and will not have accessibility issues. Please contact the instructors for further information.