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Learning of Uncertainty in an Introductory Astronomy Course in Remote Asynchronous Delivery During Covid-19 Lockdown

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Abstract

The teaching of an introductory astronomy course in remote delivery during Covid-19 lockdown encountered a unique issue in terms of a mixture of three student groups. They are the science majors, science-interested students, and non-science majors to satisfy science requirements in our Two-year community college located in New York City. The learning of how to assess uncertainty would be of universal concern in the three groups. Uncertainty examples include shoe size selection experience in daily life for non-science majors, distance measurement uncertainty for science-interested students who are parents, and simulation uncertainty for science majors. Reciting or memorizing a narrative in remote learning should be supplemented with a discussion using an alternative perspective with intellectual maturity, and the uncertainty theme would fit well for the learning of any chapters in an astronomy textbook. Assessment exercise questions are developed. The strategy to discourage rote learning and plagiarism in the remote asynchronous delivery of introductory astronomy at the college level is discussed.

Keywords: Uncertainty learning; simulation; remote asynchronous

INTRODUCTION

The Covid-19 lockdown presented challenges for instructors to deliver lessons online and students to learn remotely in synchronous, asynchronous, or mixed mode. A Harvard astronomy professor, Dr. Goodman, suggested that the teaching of uncertainty in astronomy could alleviate lockdown anxiety (Aggarwal-Schifellite et al., 2020). The details are presented in Appendix-1 for easy reference. The suggestion makes sense considering our understanding of the theory of transference learning in a setting of the introductory astronomy course being a science course for non-science college students. The present paper shows an example of teaching uncertainty and conducting assessment in a Two-year community college in New York City. Our introductory astronomy course students can be classified into three groups, namely, the non-science majors, science-interested students, and science majors. The science-interested students include those parents who want a glimpse of science to encourage their children to be majors in STEM. During the Covid-19 lockdown, the open stax astronomy textbook and other online materials were used (Fraknoi et al.; 2016). Most introductory astronomy textbook lessons would not use the uncertainty theme. Therefore, we developed examples of the logistic narrations to present the uncertainty

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subject matter as a theme in several lessons in the teaching of introductory astronomy during the Covid-19 lockdown.

LITERATURE REVIEW

In the pedagogy of physics education, the method of using Newton's laws for finding acceleration is supplemented with the alternative method of using the energy method. The ability to solve problems from the two alternative perspectives of Newton's laws versus energy method would broaden lateral thinking. The transference to the teaching of astronomy uncertainty would include the presentation of the uncertainty theme as review lessons on topics already taught in the perspective of the class textbook (Bransford et al., 2000). The uncertainty theme can be viewed as an alternative perspective versus the textbook's perspective and broaden lateral thinking. From Bloom's taxonomy application perspective, the first layer in memorization of a narrative in remote learning should be supplemented with a discussion using an alternative perspective with intellectual maturity, and the uncertainty theme would fit well for the learning of any chapters in an astronomy textbook (Armstrong, 2020).

There are several concepts in physics education pedagogy that are very useful. They are critical thinking, lateral thinking, orthogonal domains, and intellectual maturity. The critical thinking skill should be able to evaluate the statements in a judgment process (https://www.lexico.com/definition/critical_thinking). The Cambridge Dictionary explains that lateral thinking is a thinking process that uses unexpected methods for problem-solving (https://dictionary.cambridge.org/dictionary/english/lateral-thinking). Oxford Dictionary offers a contrast between the lateral thinking process with unexpected methods and the vertical thinking process with conventional logical steps (https://www.lexico.com/definition/vertical_thinking). A variation of values of a variate in one domain should not affect the values of other variates statistically in an orthogonal domain (https://www.lexico.com/definition/orthogonal). It was reported that the intellectual maturity at the level of "knowing the uncertainties" and the "fixed/growth Mindset" would form two orthogonal domains (Mandeville et al., 2018). Orthogonality exists inside a context. Within the domain of cognition, conscious and unconscious processes are orthogonal with zero measurable correlation. Within the domain of knowledge, explicit knowledge and tacit knowledge are orthogonal. Orthogonal thinker has been discussed by Curtis Odgen, Thomas W. Hass Professor in Sustainable Food Systems at the University of New Hampshire, "As a person with the ability to draw from a variety of, and perhaps seemingly unrelated, perspectives to achieve new insights" (Odgen, 2014 year). Ordgen cited several examples, including the coding notion of a gene by Schrodinger, a foundational figure in quantum mechanics. The use of orthogonal methods with different scientific principles in the study of the unfolding of protein biomolecules is well established (Temel et al., 2016).

In other words, two or more methods using independent properties to reach a common goal are orthogonal methods. In that regard, Newton's method and energy method in problem-solving would be a pair of orthogonal methods. In astronomy, the trigonometry parallax method and brightness inverse-square law method would be two orthogonal methods for the common goal of distance measurement of a Cepheid in the Hipparcos and Gaia data (Brainerd, 2020; Shanks, 2018).

Astronomers usually emphasize the concept of calibration because the Cepheid brightness inverse square law distance method is extended to distances beyond the parallax method. In other words, two orthogonal methods would share a calibration relationship when one of the methods is extended to a new range. The textbook narration using critical thinking on the statements as the first learning and the instructor uncertainty narration in the reviews of the chapters could constitute a pair of orthogonal methods to reach the common goal of intellectual maturity in pedagogy. Using the learning of uncertainty in a review to calibrate the first learning would be an acceptable pedagogy. Knowing a pair of orthogonal methods would be the beginning of lateral thinking and the becoming of an orthogonal thinker familiar with orthogonal methods and pairs with calibration applications. For example, the open stax astronomy textbook has paragraphs describing the uncertainties or chances in the cosmic impact and extinction of dinosaurs, geomagnetic storms triggered by solar eruptions, radio-active half-lives, supermassive black holes, extremely old stars, etc. The open star astronomy textbook also has external links. For instance, the link to the Torino Impact Hazard Scale in which the chance of an impact has been tabulated could be used to further discuss a cosmic impact. (Center for Near Earth Object Study, 2020).

The concepts of uncertainty and risk are essentials in economics and were formulated by Frank Knight when he was at the University of Chicago (Knight, 1922). The MIT explanation of the Knightian perspective can be summarized as the following (Dizikes, 2010). A known risk can be converted to effective uncertainty, while true uncertainty is not measurable. In the simple words of the business world from the eyes of non-science majors, and uncertainty that can be foreseen and quantified is called risk, whereas a true or genuine uncertainty is unknown in advance (Kastelle, 2013). The business perspective simply summarized that true uncertainty must be sought out to increase the opportunities for profit-making. The seeking may very well depend on lateral thinking to merge the unexpected ideas. The open text astronomy textbook paragraph narrations on uncertainties and changes can be classified as risks in using the measurements to support the associated theories. Using the Knightian perspective, a conversion of risk to effective uncertainty would need numeric steps. A numeracy aspect of chance and uncertainty at four different levels has been published by the Scot Government as a learning modulus (Scot Government-a 2020). Other professional learning modulus such as data and analysis are also available (Scot Government-b, 2020). A numeracy description would support the learning at the college level beyond news media reading of how the Titanic fate could have been affected by a geomagnetic storm (Zinkova, 2020).

The introductory courses in STEM curricula are also foundational courses for other disciplines. Calculus is required for business and economics majors. Introductory astronomy offers the fundamental science perspective to all majors when accepting astronomy as a forerunner of physics which also showed that optics was essential for the discovery of cellular structure. The alternative uncertainty theme in the reviews of astronomy chapters would present a holistic approach with an intellectual maturity perspective. Lateral thinking with two alternative perspectives in astronomy would be useful in daily life using the transference of learning.

The reduction of uncertainty is a prime objective in astronomy research, independent of the calling of Prof Goodman to use the learning of uncertainty in astronomy to reduce anxiety

in the Covid-19 pandemic (Aggarwal-Schifellite et al., 2020). Perhaps Prof Goodman was influenced by the Milky Way Radcliffe Wave discovery in which she and her collaborators were able to reduce the interstellar cloud distance uncertainty to 5% (Alves et al., 2020). The Radcliffe Wave overturned our 150-year old understanding of a ring structure in the star nurseries around the Sun and instead presented a sinusoidal structure intersecting the Milky Way galactic plane with the Sun undergoing a 13 million years period. While the deduction details of the sinusoidal stricture would not be suitable for an introductory astronomy course, the interstellar cloud distance uncertainty reduction by using the Gaia spacecraft data would be within the syllabus (Shanks, 2018).

The topic of "Life in the Universe" with the Fermi paradox is covered in the last chapter of the open stax astronomy textbook. A chapter review based on the uncertainty theme could include a discussion on the uncertainty in the scientific publications on the evolution of intelligent life. The recent astrobiology research article reporting that intelligent life is a very rare event could be discussed with the uncertainty theme while bypassing the Bayesian calculations in an introductory astronomy course (Snyder-Beattie et al., 2020)

LEARNING OF UNCERTAINTY

Uncertainty Overview

Uncertainty in science is how well do we know. We know the history of the atomic bomb and hydrogen bomb, and that knowledge eliminates the uncertainty of what causes the Sun to shine. The Sun converts mass to energy in nuclear fusion, and there is zero uncertainty that the Sun exists. We use spectroscopy data to conclude that all other stars are using nuclear fusion just like our Sun without uncertainty. The angular position information of a star on the celestial sphere has minimal directional uncertainty when compared to the distance information. A step in the cosmic distance ladder requires reference to the previous step, and the first step is the distance from Earth to Venus measured by radar technology. Radar technology started during the Second World War in the 1940s. Today radar distance measurement is accepted as real. Therefore, the reality of the stellar distance is calibrated to the reality of the radar distance from Earth to Venus. However, the uncertainty in the first step of the radar measurement will continue to the second step of stellar parallax measurement with one astronomical unit as the triangulation baseline. The third step of spectroscopic parallax or spectroscopic distance will inherit the uncertainty of the first and second steps. The accumulation of uncertainty as we go along the cosmic distance ladder is a reality that astronomers must solve. In literature, we have words to convey emotions in fiction and movies. In astronomy, we have simulations to determine the uncertainty. Therefore, uncertainty can be a productive element with diligence, humility, and aspiration.

Uncertainty in the understanding of stellar evolution

Uncertainty is an intrinsic attribute in a measurement of reality. The mere interaction of a reading of status would alter that status in the measuring process. We control the electronic uncertainty at the quantum mechanics level such that we can build smartphones. The forensic evidence from the spectroscopic analysis is a reality in legal proceedings with the usual measurement uncertainty in a forensic lab. Therefore, the spectral analysis of star signal for element identification is a reality with the usual measurement uncertainty in a

telescope dataset when compared to the reality in legal proceedings. The fuzziness of a spectral line is related to the system pressure in laser lab such that the line width of a telescope spectral line would contain surface pressure information, whether it is a main-sequence star or a red giant at the same surface temperature.

We understand the nuclear processes of the fundamental particles, including protons, neutrons, electrons, etc., in our lab at the reality level with acceptable uncertainty. In daily life, a right foot shoe size could be slightly different from the left foot shoe size, and the range of half a shoe size would be uncertain, but a pair of shoes is a reality. Therefore, the nuclear processes inside a star are a reality when calibrated to the reality of controlled nuclear reactions in a physics lab. Chapter 22 of the open stax astronomy textbook has a good narration, which is presented in Appendix-2 for easy reference.

A star having a contracting core and expanding outer layers is a reality with an analogy to the split personalities in psychology (according to the open stax astronomy textbook). This instability manifests as brightness fluctuation in variable stars and supports the reality of distance measurement, riding on the period-luminosity relationship. On the one hand, the reality of stars and remnants is calibrated to what we can control in physics labs. On the other hand, the reality of distance information is built on the radar echo from Venus for the definition of one Astronomical Unit, the average distance between the Earth and Sun, and the geometry of parallax measurement of nearby stars independent of physics principles. The next step of spectroscopic parallax or spectroscopic distance needs the knowledge of electron transitions inside an atom in laser lab, plasma interaction in energy lab, nuclear reactions in high energy lab to ascertain the reality of the location of a star. The uncertainty from the physics lab must contribute to the uncertainty in the distance determination, in addition to the uncertainty on the telescope signal. Take a daily life example. When the left foot shoe size is drastically different from the right foot shoe size in a specific custom order, the reality of a pair of shoes for a person could be in doubt because the large shoe size uncertainty in that custom order is unexpected. Similarly, the reality of distance is built on the expectation of low uncertainty.

The simulation technique used in astronomy has two aspects. On the one hand, the elucidation of physics principles can be built in terms of simulations that match observed telescope events, just like literature books have words to convey emotions in fiction and movies. To what extent would a simulation mimic an astronomical event is like to what extent storytelling could convey emotions and mimic a character a question. “The Strange Case of Dr Jekyll and Mr. Hyde” mimicked a doctor with a split-personalities and the author Stevenson wrote about the range of variety in behaviors. An author could show a character with some behavioral uncertainty in the beginning chapters to illustrate the developmental nature of a mindset. Similarly, a simulation in high-energy physics would mimic an experiment for the determination of the measurement uncertainty.

An understanding of the relationship between uncertainty and reality can transcend daily life examples to include examples in astronomy. On the one hand, applications to the

classification of objects include the star grouping in the HR diagram, the RR Lyrae grouping in a period-luminosity graph, supernova brightness versus time profile, etc. The reality of the objects is used for distance information extraction under the principle of the inverse square law in brightness. The uncertainty in the acceptance of an object designated for distance calculation will be an addition to the uncertainty in the telescope measurement of the brightness of that object. On the other hand, a virtual reality enabled by digital technology can be used for training. A simulation of an object in astronomy based on physics can be used to ascertain the evolution outcome for a given mass and reduce the uncertainty in the acceptance of an observed object with the associated characteristics. In general, the understanding of uncertainty would generate confidence in reality which includes daily life experience, astronomy studies, etc.

Uncertainty in the understanding of cosmology

Distance measurement is a necessity in the development of any civilization. The astronomy distance measurement had taken astronomers from the small distance between Earth and Venus all the way to the vast distance to the edge of the observable Universe. The Earth to Venus distance can be measured using the echo method, which is a daily experience. The time in taking a round trip will give distance information when the speed is known. Knowing that light speed is a universal constant in the physics lab, the echo from Venus's measurement was on a solid foundation. The uncertainty would not contribute much error when daily life asks for an estimation for practical purposes.

On the one hand, using Type I supernova as a standard candle allowed astronomers to estimate the distant explosion events at billions of light-years away, in exact analogy when using a standard light bulb to estimate the distance of a house in daily life such that the uncertainty would not matter much for practical purposes. On the other hand, the measurement of the separation between two regions in space across the sky is a challenge, just like a survey of the separation between two houses would cost more effort and money.

Astronomers know that the density of matter would not be uniform across the sky, just like the density of people population would be higher for regions near subway stations. Using correlation technique, astronomers found that the separation between two high matter density regions across the sky is about 0.5 billion light-years nowadays, thanks to the Sloan Digital Sky Survey data. Kepler surveyed the angular separation across the sky with an astrolabe observatory built by Tyco Brahe at the cost of a ton of gold. The angular measurement during a solar eclipse also proved that the Sun's gravity bends light and that spacetime distortion is created by a massive object from a star to a black hole such that a light path would appear to be bent. The spacetime distortion can be understood using the following scenario. A stellar-travel civilization wants to store the nuclear fuel, but the radioactive decay is a constant, so they put the nuclear fuel near a black hole with strong gravity together with strong time distortion such that the nuclear fuel at high gravity strong time distortion would retain a high number of active nuclei when compared to those stored at the low gravity of a mining site on a planet. Of course, the scenario assumes that the spaceship can escape the space distortion imposed by the black hole. Anyway, a spacetime

distortion measurement has uncertainty, just like a radioactive decay measurement has uncertainty, but the spacetime distortion by stellar mass is a fact.

Using the cosmic microwave background radiation data, astronomers know that the early universe had matter density clumping at about one degree across the sky. The hot early universe had cooled down, so the short radiation wavelength at that time has been cooled to microwave wavelength today. The control of uncertainty in the cosmic microwave radiation measurement was a lesson by itself. Recall that uncertainty can be quantified using the number of decimal places. For example, 2.75 has two decimal places would have less uncertainty when compared to 2.7 has one decimal place. Those students knowing significant figures understand that more significant figures, less uncertainty.

The first cosmic microwave background radiation measurement gave 2.7 Kelvin, one decimal place using a ground antenna, then COBE spacecraft data gave two significant figures, then the Wilkinson spacecraft data gave three decimal places, then the Planck spacecraft data gave 4 decimal places. The 4 decimal place data enable astronomers to determine that the high matter density regions are separated by about one degree across the sky in the early universe. When one degree in the early universe would correspond to 0.5 billion light-years today, the whole sky of 180 degrees would correspond to 90 billion light-years today; that is, the universe is now at 90 billion light-years diameter or 45 billion light-years radius.

Given that the time since the Big Bang event is 13.8 billion years, then space must have expanded with an acceleration such that the universe is not at 13.8 light-years radius but at 45 billion light-years. In other words, the study of distance measurement tells us that space is expanding, and astronomers called that as being dark energy driven. Astronomy is not just applied physics that matches physics lab data to the astronomy data. Astronomy shows that space has structure, just like quantum mechanics shows that vacuum has a structure called vacuum fluctuation. Since we know that the knowledge of quantum mechanics enables technology to control the electronics in smartphones, then the knowledge of space structure could enable humans to conquer the final frontier, all because of the understanding of uncertainty and the prospection on exploration to reduce uncertainty.

The establishment of 5 percent visible matter, 20 percent dark matter, 75 percent dark energy ensure that astronomy is not just applied physics but a subject to propel human experience to stars and beyond. In other words, without space expansion driven by dark energy, astronomy could be reduced to the refinement of applied physics measurements. Even if the uncertainty causes the proportions to change by 100 percent, the requirement of dark energy and dark matter in the data analysis will not go away, and that is how humans could one day take tigers to another star system, the tigers for sure cannot take themselves. A Harvard astronomy professor said that the understanding of uncertainty in introductory astronomy would reduce the students' uncertainty and stress during the Covid pandemic (Aggarwal-Schifellite et al., 2020); let us dissect uncertainty and max out the lessons on how to use the understanding of uncertainty to learn astronomy.

Prospection

The concept of prospection includes the capacity to plan. Simply remembering an event without doing an analysis may not be enough for planning. Differential analysis, under one banner or category like differential calculus of one variable, noun category such as a tool for pencil versus wrench, the 5-W (What, Who, Where, When, and Why) in the information category, then how in the function category, is an important skill. Taken from a distance, would an image reveal a pencil or a wrench under the tool category? An examination of the surrounding shown in the image could yield useful clues. Would the telescope data reveal a white dwarf pulling matter away from a red giant under the star category? The spectroscopic data of various stellar events would yield clues amid some uncertainty. Would an image of a cake reveal who did the baking under the 5-W category? An examination of the layering complexity could give clues with some uncertainty. Would an image of a planet reveal which telescope did the imaging under the 5-W category? An examination of the image resolution could give clues with some uncertainty. Would an image of a campfire reveal how the fire was generated under the function category? The image of a pile of wood or a can of propane would reveal the mechanism without much uncertainty. Would a telescope image of an open cluster reveal how the zero-age main sequence supported the outliers in the function category? An examination of the turn-off point with references to other open cluster data would yield clues with some uncertainty. A list of possibilities under a category can be generated by using the extent of uncertainty as to the criterion for the ranking of the possibilities. The differential analysis includes the generation of such a list and the understanding of uncertainty, which rides on the reduction of the uncertainty percentage in the data collection process. The application of differential analysis to prospection enables realistic planning on future telescope missions and encourages the taking of initiatives in expanding the knowledge of astronomy. The application of "taking initiative" as the intent of learning is also important in pedagogy. On the one hand, the request of providing one example could serve as a simple measure of rote learning, the first layer of memorization in Bloom's taxonomy. On the other hand, the open question of providing at least one example could serve as a simple measure of the taking of initiative. The overcoming of any anxiety on the outcome uncertainty while "taking initiative" would positively shape prospection, an important learning tool to continue the pursuit of Bloom's taxonomy layers to understand, apply, analyze, evaluate and create.

ASSESSMENT

Assessment Level One

The assessment exercises can be conducted as fill-in-blanks with the first alphabet already given. The Make-corrections method is another assessment exercise. The logistic narration is presented in Appendix-3 for interested instructors to select the appropriate materials. Here is an example of fill-in-blanks. "Star Trek described space as the final frontier. The exploration of frontier usually includes the ability to effectively handle u____ (uncertainty). The challenge of uncertainty in exploration must be considered when deciding what the tools and e_____ (equipment) to bring along. Planning or prospection of the possible challenges would require s_____ (simulations) of possible scenarios with uncertainty."

Make-correction method example is presented as the following. "The Star Trek prime directive of not interfering with cultural delivery (development) would mean that a spaceship must hide its emissions or mimic its emissions as regular emissions from stars, active catalytic (galactic) nucleus, etc. An emerging civilization with infantile space technology should not be aware of the presence of a prime-directive ship (spaceship). On the one hand, the captain of a prime-directive spaceship would mimic the spaceship emission as the emission of a Cepheid, Super Bowl (Supernova), etc. One the other hand, an infantile space technology civilization would study stellar emissions and eliminate untidiness (uncertainty). " (Note that Super Bowl is a football event in the United States)

Assessment Level Two

The assessment level two exercises contained deeper questions. The logistic narration as a database to generate related questions is presented in Appendix-4. Here are two assessment exercise examples. "Engineering predated a_____ (astronomy) and physics. Examination and test in education predated the testing of h_____ (hypothesis) formulated by the inductive reasoning in scientific experimentation; and the testing of physics known theories on experiment outcomes using deductive r____ (reasoning) in phenomenology. It does not matter what predated what, uncertainty is presented in any m_____ (measurements), with useful information in some cases."

"Examination and test in education is the evaluations of the performance of the studios (students) in terms of the grade point average. On the hand, the uncertainty of the grade point beverage (average) of a student could be a few percent with forty courses in a typical college curriculum of a typical student with dormitory support. On the other hand, the uncertainty in the distance of an astronomical subject (object) could be more than 100 percent, for instance, the interstellar lust (dust) could have blocked a signal and the distance-square calculation of the intrinsic luminosity divided by telescope measured brightness would then contain large unexpected (uncertainty). A larger than expected uncertainty in the grade point averages of students in a given glass (class) could mean that the class environment had a diverse student population in terms of pre-requisite grades, study-work ratio, etc. A large uncertainty in an observed spectroscopic lime (line) of a star can be measured as a large width in the spectrometer and could mean a high pleasure (pressure) environment indicative of a zero-age mane (main) sequence star, instead of a super red giant."

Assessment of Writing

Our Two-year community college students need reading remediation. Dictionary references are important tools. For instance, the meaning of knowledge as fact information and would explain the need for critical thinking on uncertainty to separate fact from the information. (https://www.lexico.com/definition/knowledge).

The meaning of dimension being an aspect of a situation (https://www.lexico.com/definition/dimension) and the meaning of keyword being a great significant concept (https://www.lexico.com/definition/keyword) would explain the number

of keywords as the number of orthogonal aspects or dimensions. The Cambridge dictionary sentence example of "De-correlating their responses to extract orthogonal dimensions requires calculation" should be within the college reading level when students understand" de-correlating" as "separating" without knowing the details of the statistical calculation. (https://dictionary.cambridge.org/dictionary/english/orthogonal)

The make-correction exercise would serve as a preliminary assessment of writing with the perspective that precise reading skill is important to support writing. The assessment of writing conducted using an essay on a given title would pinpoint a specific context corresponding to some general outcomes. Constraints such as asking for writing based on a list of keywords would focus on the selected keyword concepts and their relationships. This kind of essay writing usually would be given a duration of a day or more, with some probability that some students would engage in plagiarism. The distinction of content words and function words such as auxiliary verbs, prepositions, etc., in speech articulation, has been emphasized (Baruch; 2020). Given a list of keywords, an exercise would ask the students to supply additional function words (not verbs, not nouns, not adjectives, not adverbs) and write a complete sentence with maximum meaning in astronomy. The emphasis is on "Do not add nouns, adjectives, verbs, adverbs" in order to preserve the content words. A daily life example used to demonstrate the supply-function words exercise to the students was a list of the following words, "Boy, Movie, Ice cream, Seeing, Enjoy, Funny". The designed answer was "The boy enjoys ice cream when seeing a funny movie." When a student wrote, "The movie enjoys a boy when seeing a funny ice cream", then an instructor would assess the pre-requisite and know that the basic remedial reading skill was missing. Normally an instructor would not grade the pre-requisite, but the assessment of pre-requisite is important when a pre-requisite was taken in the Spring Semester 2020 Covid-19 lockdown with a different grading policy from college administration due to the sudden switch to online instruction. Our Two-year community college is in New York City, and students speak more than 100 mother tongues. An emphasis on the difference of function words versus content words would inform an instructor on the level of the verbal pre-requisite of the students.

An astronomy example would be "Spiral, Star cycles, Region, Observed, Arm, Galaxy" The correct answer was "Star cycles are observed in the spiral arm of a galaxy". When a student submitted a wrong answer such as "Spiral arm is observed in the star cycles of a galaxy", an instructor would offer precision correction according to the specific mistakes made by an individual student. When the mistakes are in the function words, the correction from an instructor would be effective in general education beyond the learning of astronomy. The strategy of the replacement of content words with non-words while keeping the function words has been used in brain research based on fMRI and MEG scans. The data showed that the posterior temporal lobe plays an important role in syntax processing (Matchin, et al., 2019). It was reported that the frequency motif of the local distribution of content and function words is related to the principle of minimal cognitive loading (Liang, et al., 2019). Individual language style in terms of context words and function words has been studied (Müller-Frommeyer, et al., 2020). Given these neuroscience results, the mistakes in the function words would let an instructor to deliver precise education. For these remedial

reading students, the understanding of uncertainty in astronomy could be achieved more readily when expressed in terms of numeric percentage values using elementary arithmetic steps.

Writing plagiarism could be reduced when given a short assignment in a short duration. Submission of the wrong answers listed above to one of the plagiarism remover websites (https://www.plagiarism-remover.com/) was conducted. The echoed answer was, "The movie delights the boy when he sees the funny ice cream. The burning arm is seen in the orbits of the galaxy" It appears that the supply-function words assessment would not be corrupted by online plagiarism remover software at this moment. A recent paper on deep machine learning showed the use of a diagram consisting of the keywords with arrows suggesting the possible relationships (Manning, et al., 2020). The sentence "The chef who ran to the store was out of food" was used. The content words are "chef, ran, store, food" and the function words are "the, who, to, was, out, of " (Webb 2020). An alternative sentence, "The chef ran to the store with food", could mean a food delivery to a specific store by a specific chef. When the word "out" is given, the sentence "The chef ran out of the store with food" could mean that the chef took the food and left the store due to non-payment. At this moment, it appears that linguistic software would not offer advantages in plagiarism when students are asked to make a sentence with given words in context to demonstrate astronomy learning.

FINDING AND DISCUSSION

The learning of "how to describe or assess uncertainty" would be of universal concern for all students. A recent dopamine study showed that most people could not use the "very mild stress" as stimulation to increase their executive function capability, in contrary to the common expectation that a small amount of stress for the raising of dopamine could facilitate the executive function in the cognition process (Zareyan, et al., 2020). Familiarity with the uncertainty in introductory astronomy would be transferred to a deeper understanding of uncertainty in general and could reduce daily life stress due to uncertainty. The assessment exercise questions drawn from our database listed in the appendices are meant to be inclusive. The fill-in-blanks format can be transformed to multiple-choice and true/false formats. The testing of the ability to weed out false information in the multiple-choice and true/false formats could be used in the grading of performance. The true/false format extension to the true/error format with error correction would emphasize the concepts of uncertainty and falsehood. The make-correction format directly reinforces Bloom's taxonomy first layer of memorization by using the typo mistakes to draw attention. An important narration on specific concepts for memorization would be delivered as a make-correction method in the remote delivery mode within a short duration; in contrary to the standard reading comprehension method in which students read a narration and do multiple-choice questions in some duration. The short duration is an important strategy to discourage plagiarism. An assessment rubric example is presented in Table 1

Table 1 Assessment rubric example of the learning of uncertainty

Deliverable	Competent	Needs improvement
Fill-in-blanks uncertainty questions (25%)	Above 75% score	Below 75% score
Make-correction uncertainty questions (25%)	Above 75% score	Below 75% score
Supply function-words uncertainty questions (25%)	Above 75% score	Below 75% score
Prospection short essay (25%)	Above 75% score	Below 75% score

An assessment dataset showed that about 30% of students are at the competent level, 20% at the need-improvement level, with a 50% drop out rate for N = 60 students in the assessment study. The Covid-19 lockdown remote class has a high dropout rate when compared to the 15% dropout rate in a regular face-to-face class in previous semesters. Whether the inclusion of the uncertainty theme to discourage remote learning plagiarism had increased the dropout rate would need more data in further lockdown situations.

CONCLUSION

The teaching of introductory astronomy with the theme of uncertainty is presented. The assessment exercises in terms of fill-in-blanks, make-correction, and supply function-words were used to generate deliverable data to support the assessment rubric while discouraging plagiarism. The uncertainty theme with narrations in astronomy topics is listed in the appendices for further development by interested instructors.

Limitation & Further Research

The limitation of the study included the use of a relatively small database of 60 students, the exclusion of a longitudinal study due to the absence of a second-semester astronomy course, the absence of a double-blinded project in which the assessment investigators should be different from the course instructors, the effect of Covid stress on the studied students, and the assumption of zero plagiarism in remote asynchronous delivery. A strategy to discourage rote learning and plagiarism in the remote asynchronous delivery of introductory astronomy at the college level could include questions from the perspective of uncertainty. The assessment questions would take time to proliferate across the web,

with students uploading questions and sharing plagiarism. The novel pedagogy in the use of uncertainty as one of the teaching themes in introductory astronomy would be useful even in complete reopen after the lockdown. On the one hand, eventually, the learning of uncertainty could become a rote learning exercise, just like the calculator button on standard deviation offers numeric answers in a lab setting without an understanding of the basic Bell curve statistics. On the other hand, the proliferation of using the uncertainty theme as a review of astronomy in introductory astronomy would fulfill the suggestion of Professor Goodman to use the learning of uncertainty to reduce anxiety in the Covid-19 pandemic (Aggarwal-Schifellite et al.; 2020). The uncertainty description narration in the appendices is conceptual writing for easy adaptation to various questioning formats. An application of artificial intelligence writing software by an instructor could also generate different copies for different student groups in each class. Microsoft just bought the OpenAI writing software technology (Scott 2020). It is expected that other anti-plagiarism software companies and university writing centers would also use artificial intelligence writing software.

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APPENDIX I HARVARD GAZETTE EXCERPT OPEN ACCESS

Start excerpt

https://news.harvard.edu/gazette/story/2020/07/3-takes-on-dealing-with-uncertainty/

For many people, measuring uncertainty seems impossible. For astronomer Alyssa A. Goodman, the variable is integral to the study of the universe.

"In astronomy … estimating uncertainty is just about as important as making the measurement itself. We're talking calculations where a part in a million makes a completely gigantic difference in the story of the universe, so we have to be very careful about the answers," said the Robert Wheeler Willson Professor of Applied Astronomy, co-director for science at the Radcliffe Institute for Advanced Study, and research associate at the Smithsonian Institution.

Being comfortable with uncertainty is essential to astronomers who often can't conduct experiments in controlled environments like other scientists, Goodman said. She even thinks astronomers can teach the rest of us how to understand and accept uncertainty as a necessary and useful part of life.

"Astronomers have to deal with uncertainty every day in our work. [We] can't move a star or get a different angle … we have to be very serious about clever ways to estimate uncertainty in the absence of more information," she said. "In the case of COVID-19, right now what we suffer from is a tremendous lack of reliable data, and to make predictions in the absence of reliable data is extraordinarily difficult. [But] it's not impossible, and I think it's important that people appreciate that."

(end of excerpt)

APPENDIX II OPEN STAX ASTRONOMY EXCERPT OPEN ACCESS

An excerpt from open stax astronomy textbook chapter 22. (Start quotation) "Most stars actually generate more energy each second when they are fusing hydrogen in the shell surrounding the helium core than they did when hydrogen fusion was confined to the central part of the star; thus, they increase in luminosity. With all the new energy pouring outward, the outer layers of the star begin to expand, and

the star eventually grows and grows until it reaches enormous proportions. When you take the lid off a pot of boiling water, the steam can expand, and it cools down. In the same way, the expansion of a star's outer layers causes the temperature at the surface to decrease. As it cools, the star's overall color becomes redder. (We saw in Radiation and Spectra that a red color corresponds to cooler temperature.) So, the star becomes simultaneously more luminous and cooler. On the H–R diagram, the star therefore leaves the main-sequence band and moves upward (brighter) and to the right (cooler surface temperature). Over time, massive stars become red super-giants, and lower-mass stars like the Sun become red giants. (You might also say that these stars have "split personalities": their cores are contracting while their outer layers are expanding. (Note that red giant stars do not actually look deep red; their colors are more like orange or orange- red.)" [End Quotation]

APPENDIX III ASSESSMENT LEVEL ONE USED IN PROJECT

Star Trek described space as the final frontier. The exploration of frontier usually includes the ability to effectively handle uncertainty. The challenge of uncertainty in exploration must be considered when deciding what the tools and equipment to bring along. Planning or prospection of the possible challenges would require simulations of possible scenarios with uncertainty.

The Star Trek prime directive of not interfering with cultural development would mean that a spaceship must hide its emissions or mimic its emissions as regular emissions from stars, active galactic nucleus, etc. An emerging civilization with infantile space technology should not be aware of the presence of a prime-directive spaceship. On the one hand, the captain of a prime-directive spaceship would mimic the spaceship emission as the emission of a Cepheid, Supernova, etc. On the other hand, an infantile space technology civilization would study stellar emissions and eliminate uncertainty.

Besides the search for advanced civilization, astronomy studies also include the search for life, that is, all kinds of life forms. Mars possess local environments with conditions similar to some of Earth's extreme environments containing extremophiles. Gravity-assisted spacecrafts routinely travel inside the solar system in search of solar wind effect, extremophiles, etc. A spacecraft usually carries at least two two antenna systems due to the uncertainty in signal communication.

The astrolabe built by Tycho Brahe, considered to be exquisite and expensive at the time, had enabled angular position data collection with less uncertainty. The data were used by Kepler to show the elliptical orbit of Mercury with little uncertainty and provide further support for the Copernican revolution of a hello-sphere.

Fast forward to the 20th century, the 100-inch telescope at Mount Wilson resolved the details of a galaxy to provide evidence of a galaxy with little uncertainty, although the Cepheid variable distance method already showed the mega light-years distance to Andromeda Galaxy, when measured from the Milky Way Galaxy that the Sun-Earth resides. The seeing is believing of a galaxy is based on the reduction of uncertainty in seeing when compared to the deductive reasoning on the distance method.

The firmly established astronomy fact on the existence of galaxy in the 20th century had enabled astronomers to understand the vast space in terms of 90 billion light-years in diameter and the 13.8 billion years duration since the Big Bang starting of the Universe.

APPENDIX IV ASSESSMENT LEVEL TWO USED IN PROJECT

Engineering predated astronomy and physics. Examination and test in education predated the testing of hypothesis formulated by the inductive reasoning in scientific experimentation and the testing of physics known theories on experiment outcomes using deductive reasoning in phenomenology. It does not matter what predated what, uncertainty is presented in any measurements, with useful information in some cases.

Examination and test in education is the evaluations of the performance of the students in terms of the grade point average. On the other hand, The uncertainty of the grade point average of a student could be a few percent with forty courses in a typical college curriculum of a typical student with dorm support. On the other hand, the uncertainty in the distance of an astronomical object could be more than 100 percent, for instance, the interstellar dust could have blocked a signal and the distance-square calculation of the intrinsic luminosity divided by telescope measured brightness would then contain large uncertainty.

A larger than expected uncertainty in the grade point averages of students in a given class could mean that the class environment had a diverse student population in terms of pre-requisite grades, study-work ratio, etc. A large uncertainty in an observed spectroscopic line of a star can be measured as a large width in the spectrometer and could mean a high pressure environment indicative of a zero-age main-sequence star, instead of a super red giant.

The uncertainty in the orbit of Uranus led astronomers to examine the data and determine the origin of the uncertainty. When the uncertainty was not random, astronomers studied the possibility of another planet that would gravitationally tucked onto Uranus. Neptune was found in theory and confirmed by observation using the phenomenology approach.

Astronomers know that there are 5-percent visible matter, 20-percent dark matter and 75-percent dark energy in the Universe that started 13.8 billion years ago with a current diameter at 90 billion night years. The electromagnetic radiation from radio to Gamma Ray wavelengths reveals the visible matter, the gravitational pulling of dark matter keeps a galaxy together, and the space expansion driven by dark energy are conclusive due to our understanding of the uncertainty in astronomy.

The conquering of uncertainty was necessary in the exploration of North Pole, South Pole, etc. Similarly, the understanding of uncertainty in astronomy and the conquering of uncertainty put humans on the Moon, and beyond.