Self-Guided Tutorials and Review Materials for General Astronomy

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Abstract

We are developing a suite of interactive astronomy resources for use in a distance education course for undergraduate non-science majors. The course is structured for qualified high school students throughout the Southwest Border Region as well, who will earn NMSU college credits for completing it while still in high school. A primary goal is to allow students who are unable to commit to twice-weekly sessions of classroom and laboratory attendance at NMSU, due to geographical or time constraints, to successfully study science at the college level.

We present here a prototype interactive database for such an undergraduate astronomy course. It has been constructed using a combination of open source packages, and contains text, image, and publication quality equation components. Students select from a range of topics, and then challenge themselves with a randomized selection of questions to test their understanding of key science and mathematical topics. All questions contain HTML links to question-specific hints and to relevant lecture notes. Real time grading and detailed solutions provide instant feedback, and the large content pool (5,000 questions) insures that each quiz is a unique experience. User progress is tracked thoroughly, allowing a review of all student activity throughout the semester and for automatically generated review quizzes which focus on the material which an individual needs to study most.

We discuss the motivations for constructing a "Do-It-Yourself" database, rather than using commercial course management systems. A solution of this nature provides significant flexibility in determining the format and style of review and user-interaction, with material and questions personalized to each individual student's strengths and weaknesses by topic. One of the great tools for bringing astronomy to life for non-science majors is the wealth of images of astronomical objects throughout the Universe; with this system we are able to support a large archive of such material within our database.

Introduction – Challenges in Distance Education

Distance education is strongly supported by NMSU, with a dedicated vice provost position, yet it is still in its infancy (2,500 students enrolled this spring, and participation is currently increasing by 55% per year). Current efforts include a variety of undergraduate courses which incorporate the internet into course delivery to a limited extent (e.g., class notes on the web), and a pilot program which offers complete distance access for a subset of the graduate curriculum in three disciplines. These programs represent a significant compromise between availability and depth of coverage – either accessible to a broad range of students but functioning as an adjunct to required in-class sessions, or providing near stand-alone functionality for a very limited number of courses in specific postgraduate fields.

A logical next step is to provide complete distance access for general education courses. The NMSU undergraduate program is the primary entry point into higher education for most state residents. However, many have limited access to the daily in-class sessions of the traditional academic path due to geographical limitations (e.g., living in remote rural areas) and, just as crippling, time constraints (e.g., working full-time during business hours, child care issues). By providing distance access to our core curriculum we will broaden the participation of underrepresented groups throughout the region, by allowing them greater control over the location and the scheduling of their studies. It will also draw into higher education underserved individuals who would otherwise have no viable opportunity to consider a career in the sciences.

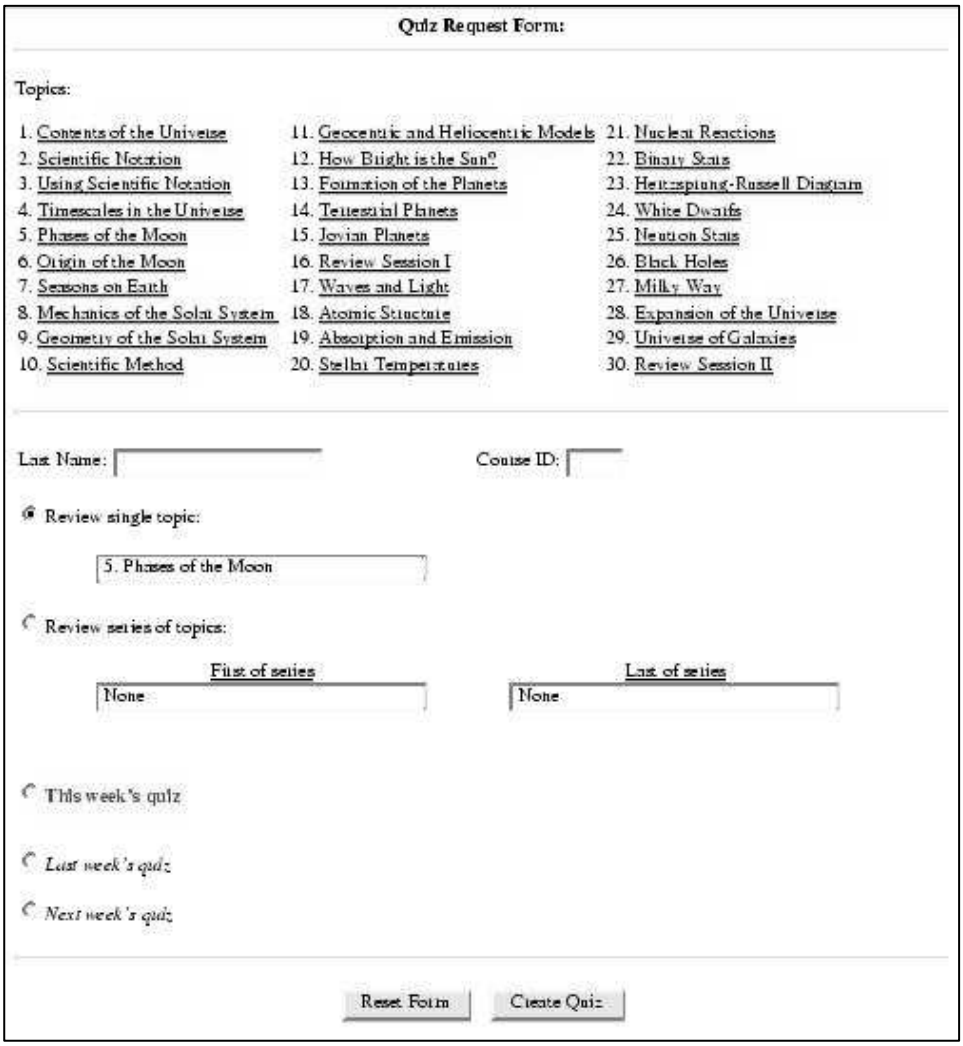


Figure No. 1 - A sample web page from within the interactive quiz environment, showing the primary user interface. Students select from a full set of topics listed at the top of the page (with links back to complete lecture materials), or choose to review the weekly lectures. Once the user name and password are approved, a five question quiz is instantaneously created and provided to the user in HTML format.

Recent studies (NSF {1}) have correlated poverty and lower levels of parental education to student failure in STEM fields; both of these factors are highly significant locally. In the Deming school district, 100% of students receive free or reduced-cost meals. The average median household income of $20,181 is well below the state average, and the unemployment rate of 17.5% is the second highest in the state. Deming is thus a targeted economic enterprise and development area, well suited to a pilot program to increase participation in the New Mexico higher education system. Our intervention targets for a dual enrollment college course in astronomy will be selected at the high school level, where the decisions of whether to attend college and to consider a major and/or career in the sciences are critical.

We thus intend to extend the traditional audience for distance education to embrace local high school students. This will encourage student enrollment at university upon graduation, will give students a "head start" by fulfilling science course requirements while still in high school, and will encourage them to continue STEM class work by providing a well-mentored first experience in college-level science, guided by daily sessions with K-12 educators. The hybrid course under development allows a local K-12

science educator in Deming to act as a facilitator for the online college-level NMSU course. We thus combine a tested, well-developed course syllabus at the college level with daily interaction and individual support to enable high school students to manage their activities and work load throughout the semester.

The following tasks represent three key steps necessary to provide a general astronomy course in concurrent enrollment format, within the college of extended learning. We will focus the rest of this paper on the third topic: an interactive review database for general astronomy.

I. Multimedia Development

We are recording and annotating video for a full semester of lectures, with introductory material to make them appropriate for use at the college and at high school level. Each lecture covers a single set of lecture slides, available in HTML format, augmented by a small number of diagrams drawn during lecture, which will be recreated and made available online. The eTEACH open-source model developed at the University of Wisconsin (Foertsch et al. {2}) will be used to coordinate video and web-based information.

II. Laboratory Exercise Adaptation

Astronomy is unique among the physical sciences in offering viable opportunities for laboratory work through distance education. We are adapting computer-based experiments (e.g., exploring planetary motions by applying Kepler's laws to tabulated observations, see also Bothun & Impey {3}) and hands-on activities (e.g., building a model comet from basic ingredients, measuring redshifts from galaxy spectra) for internet access. Guided observations (e.g., predicting the phase of the Moon, observing eclipses, tracking the constellations), with significant guidance from weekly sky charts and guided discussions of the mechanics of the night sky, and monthly on-site observing sessions for one-on-one interaction, will be combined with one of the greatest assets of southern New Mexico -- our clear, unpolluted skies!

III. Interactive Quiz Environment Development

We are developing an online database of 5,000 comprehension questions, keyed to each week's reading and discussion material and large enough that a student can retake weekly self tutorials multiple times, with new problems, in order to master the material via self-guided review. Problems contain hints ("?" symbols on figure) and solutions, cross-linked into lecture HTML pages ("i" symbols on figure), so that incorrect answers lead students back to the key material for immediate review.

A complete record of every quiz experience is stored for each individual student. When studying for exams, students thus have the option to request tailored review quizzes. These are created in real time, and focus exclusively upon the material which they personally found most challenging to date. The database is C- and PERL-based, allowing fast, random selection of questions from a large reservoir and automatic grading and guided feedback in real time through web browsers. Initial tests are positive, with a fully functioning database of 2,500 questions running online in beta-test mode.

Course Management Systems – Options

Conventional course management systems (e.g., Bulletin Board, WebCT) offer a set of clear features. A uniform appearance across a range of university courses provides a single, consistent interface for students; hardware is provided and supported externally; pre-generated, pre-tested materials are often available. However, on the balance, many systems enforce strict limitations on the underlying structure and format of material and on the user interface; disk allocation (e.g., space for astronomical images) can be quite limited; opportunities for personalizing material (either by the instructor to suit their goals or by the students to meet their individual needs) are constrained, forcing a generic experience for all students; a complete record of student performance is rarely available to the instructor. In addition, issues of copyright to original materials become more complex, and certain systems (e.g., those supported by textbook publishers) require the purchase of expensive texts by students as a condition of access.

Sample Self-Guided Review Tutorial (Solution Page)

#1. A primary advantage of the Hubble Space Telescope (HST) over ground-based telescopes is that:

- HST orbits high above the surface of the Earth, and thus lies closer to the stars being observed.
- HST's primary mirror is larger than that of any optical telescope on Earth.
- there is no gravity in space, whereas telescopes on Earth are bent by their own weight.
- starlight which reaches ground-based telescopes has been distorted by fluctuations in the Earth's atmosphere.

The Earth's atmosphere is thick both of particles, all continuously in motion, and light from distant objects is distorted as it passes through this uneven medium. This causes them to appear blurry when we observe them through ground-based telescopes. (The same *seeing* effect is responsible for the twinkling of stars that we view by eye - if our planet had no atmosphere then the stars would appear to shine steadily.) As HST orbits the Earth well above the atmosphere, distant objects appear with greater clarity in its cameras.

Though HST does orbit 600 kilometers above the Earth's surface, this extra height is flat, far less than the distance to the Moon (384,000 kilometers), let alone the distance to the nearest star (40 trillion kilometers). Like all small objects orbiting the Earth, HST experiences a sensation of weightlessness. (While the gravitational attraction of the Earth is still present in space, the telescope is in *free-fall*, as we discussed in lecture.) The design team did not have to compensate for *flexure* due to the telescope sagging under its own weight as it changes position, as must be done for large ground-based telescopes. The HST mirror has a diameter of 2.4 meters, while the largest ground-based optical telescopes have diameters of 10 meters (17 times the collecting area); a 2.4 meter lens was the largest that could be placed in orbit when HST was created. HST must thus spend considerable time observing faint objects, in order to collect enough photons.

#2. The figure drawn below contains an optical spectrum of a galaxy. What type of spectrum is it?

- absorption
- continuum
- emission

This is an *absorption* spectrum, such as we might find when observing an elliptical galaxy. The key characteristics are a smooth distribution of continuum which stretches across all wavelengths, broken up by deep troughs of absorption (dark bands) at a few scattered wavelengths.

#3. If the Moon is visible above the horizon from mid-afternoon (3pm) until early morning (3am), what phase will it have?

. . .

Redo Quiz | New Quiz | Stop Quizzing

Figure No. 2 - A sample web page from within the interactive quiz environment, showing the form of the solution pages for a short quiz. Both the correct answer and the student's guess are identified for each question (incorrect guesses are highlighted in red). Text and images explain how to solve the question, while two buttons at the bottom of each question provide specific hints for setting up the problem clearly ("?") and a link back to relevant lecture material ("i").

Self-designed systems such as our model offer complete control over micro- and macro-format and options, in direct contrast. Updates to materials and to the user interface are instantaneous, and we can provide semi-infinite amounts of disk space. We can also optimize an extensive cross-linkage between varied materials on one site (e.g., tying lecture notes to video demonstrations of experiments, with both accessible from relevant review questions). We caution that such a program requires significant development of new course-specific materials, in addition to the development costs for database access and security protocols, and there are local hardware and software maintenance demands to support.

System Structure – The Self-Guided Astronomy Tutorial

The major component of our system are (1) a set of lecture notes, with both text and interactive diagrams, and embedded links to external sites, tied to (2) a set of lecture and laboratory video presentations, and (3) an interactive evaluation database of 5,000 questions. The system is available 24x7 through the internet, and provides instantaneous feedback for student work, and progress record updates. The instructor can access a complete set of records for each student's progress (including all problems attempted, and the specific form of any incorrect answers submitted), sorted by date or by topic.

Student privacy is maintained, the system is resistant to hacker attacks, and instructor course material access can be limited to registered students. The user interface works through HTML forms. The server is accessed through a set of compiled C scripts (optimized for system security), which control a set of PERL scripts for the database access (optimized for speed and for record keeping). The design represents a balance of internal functionality and user comfort (ease of use).

The primary interface for quiz review is shown in Figure 1. Once a topic has been selected for review, the user is provided with a five question quiz (Figure 2) to complete in a thirty minute interval (the time limit is set to prevent students from struggling endlessly with a particular question, to encourage them instead to return to lecture notes and videos for review and then to re-attempt the material with another quiz). The quizzes are presented in three modes: (1) practice mode, where students select questions by topic and are provided with question-specific hints and links back to lecture materials (Figure 3) for every question, (2) evaluation mode, weekly questions which sample current topics to test understanding and identify topics for further study, and (3) review mode, for use in studying for exams, where students request questions taken from their individual weakest areas as established by their work throughout the semester. All quizzes are graded instantly, and a complete solution is provided for each problem. The large database allows students to retake quizzes on any topic with similar, but unique, questions for as long as they wish to do so.

The instructor can access complete student records, providing a measure of the total class performance on every topic and a detailed measure of each student's individual work. A record of the student's answer is preserved for every attempt (providing insight into patterns of failure). Instructors can thus "walk through" every quiz taken by a student throughout the semester (allowing a starting point for targeting one-on-one discussions), or track student success by topic or by date.

Conclusions

The challenges of providing science coursework through the distance education model are many and varied, including providing a dynamic laboratory experience safely and with sufficient guidance, generating lecture materials with the latest generation of inspiring astronomical images and sufficient guidance for material which may be completely unfamiliar to students, and creating opportunities for students to self-evaluate their progress frequently (and fairly painlessly) on their own schedules.

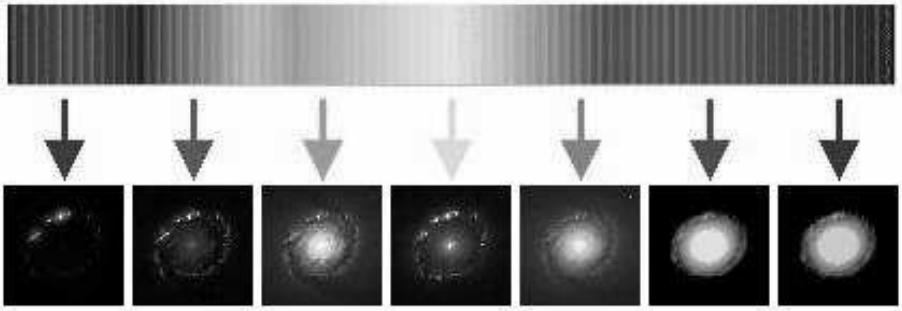
We are designing a suite of interactive astronomy resources for such a course, for the undergraduate and high school populations of the Southwest Border Region. Our program utilizes open source packages to create text, image, and publication quality equation components. Local hosting allows for complete control over the user interface, the database of astronomical materials, and extensive student records. In closing, we wish to share the explosion of imaging and spectral data generated by the latest generation of telescopes and spacecraft across the electromagnetic spectrum with the next generation of scientists of America.

There are two basic ways to observe a galaxy with an optical telescope: by taking an *image*, or a *spectrum*. A telescope takes an image of a galaxy just as you might use a camera and black and white film to take a picture of a yourself.

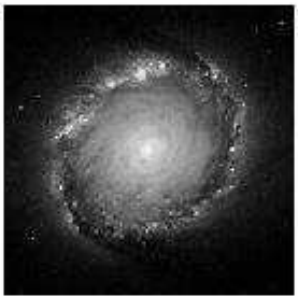
In each case, all of the light from the object is collected; areas which emit the most light (or, in the case of clouds and snow, reflect the most sunlight) appear as bright regions on the pictures, while fainter areas are reproduced in dimmer shades. Such an image conveys the overall brightness of the galaxy, but it cannot show us the colours of the stars which make up various parts of the galaxy, nor how these colours vary with location within the galaxy.

In order to produce a colour image, we need to take multiple exposures at different wavelengths along the optical portion of the electromagnetic spectrum. A different filter is placed before the camera for each exposure, one which transmits light within only a narrow range of wavelengths. By combining the exposures, we can determine which parts of the object are brightest at short wavelengths (ultraviolet light, and blue colours), at intermediate wavelengths (yellow colours), or at long wavelengths (red colours, and infrared light). For spiral galaxies like our own Milky Way, for example, we find that the outer regions in the galaxy disk tends to have blue colours (showing the presence of bright, young stars), while the central bulge is populated by redder, longer-lived stars.

The figure below shows seven images of the galaxy NGC1512, which was observed with the Hubble Space Telescope. Each image was taken through a different filter, and so sampled a different portion of the spectrum, and contains light of different colours. Observe how different parts of the galaxy brighten and assume prominence at different wavelengths. If you were describing the morphology (appearance) of this galaxy, how might your description change if you looked only at one short wavelength image, or only at one long wavelength image?



By combining the images, we can create a single colour image of the galaxy. Could you predict from the initial black and white images which components of the galaxy would be brightest in various colours?



A *spectrum* takes the idea of breaking down the light according to colour, or wavelength, one step further. Just as droplets of water in the atmosphere can separate out the colours of the sunlight into a rainbow, or a prism can split up white light into a range of colours, a *spectrograph* can disperse the light emitted from an object according to wavelength ...

Figure No.3 - A sample web page from within the online course lecture material, developing the concepts of imaging and spectroscopy. Multi-band HST imaging of a spiral galaxy is used to illustrate the changes in morphology and stellar populations observed at different wavelengths.

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Biography

Nicole Vogt is an assistant professor in the astronomy department at New Mexico State University. Her current research efforts are focused on understanding the formation and evolution of galaxies over the history of the Universe. She observes their individual properties, and interactions between galaxies, with the largest telescopes in the world, including the optical Keck 10-m Telescopes and the New Mexican Very Large Array of radio telescopes. She is currently a principal investigator on the Hubble Space Telescope, using the Space Telescope Infrared Spectrometer to study the formation of central bulges in galaxies similar to our Milky Way.