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The General Education Astronomy Source (GEAS) Project: Extending the Reach of Astronomy Education

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Abstract. We present a set of NASA and NSF sponsored resources to aid in teaching astronomy remotely and in the classroom at the college level, with usage results for pilot groups of students. Our goal is to increase the accessibility of general education science coursework to underserved populations nationwide. Our materials are available for use without charge, and we are actively looking for pilot instructors.

Primary components of our program include an interactive online tutorial program with over 12,000 questions, an instructor review interface, a set of hands-on and imaging- and spectra-driven laboratory exercises, including video tutorials, and interviews with diverse individuals working in STEM fields to help combat stereotypes. We discuss learning strategies often employed by students without substantial scientific training and suggest ways to incorporate them into a framework based on the scientific method and techniques for data analysis, and we compare cohorts of in-class and distance-education students.

1. Overview of GEAS Teaching Resources

The General Education Astronomy Source (GEAS) materials can be divided into four broad categories for use in teaching general astronomy at the college level.

- An online tutorial program (the self-review library) covering general astronomy concepts, allowing instantaneous review with individualized feedback and available 24/7.
- An instructor interface to allow evaluation of and guidance for a cohort of students and one-on-one review of individual efforts.
- Sixteen weeks of hands-on and data-driven astronomy laboratory exercises, with multiple support options for students working alone.
- A suite of short films emphasizing the diverse nature of inspirational individuals working in astronomy-related fields.

2. The Self-Review Library

2.1. Student Usage

The GEAS self-review library is built around 26 modules, each based on a 75-minute lecture. The modules follow a common pattern for a semester-long college course in general astronomy, covering both solar system topics and the larger Universe. Each module is presented through a series of web pages (200+ in total), augmented with audio recordings and reproductions of white board diagrams from conventional classroom lectures.

Material is presented at a appropriate level for non-science majors, with a balance between qualitative and scaling arguments and numerically motivated ideas. The basic mathematics needed for the material (algebra, roots, exponents, and scientific notation) is defined early on and reinforced throughout the entire sequence. The art of visualization is presented as an important problem-solving strategy and emphasized for topics for which it is most useful (e.g., understanding the phases of the Moon, eclipses, and orbital mechanics).

Students interact with the self-review library by completing sets of five-question quizzes. Each question is presented with two aids: (1) a link to a tailored hint, and (2) a link to an appropriate lecture slide from the parent module and an accompanying lecture audio segment. Students can thus refresh the connection between a specific question and a general topic or receive guidance on how to set up or think about a problem. Students are presented with a solution set roughly two seconds after submitting their work, one of which shows both correct answers and submitted answers for comparison. Numerical solutions are shown step by step so that they are easy to follow. The extensive database of more than 12,000 sets of questions, hints, and solutions allows students to review new concepts for as long as they wish without repeating questions.

On average, students using the GEAS ssytem solve over 1,600 questions in a semester. They either follow a semester-long sequence of extensive practice and weekly formal quizzes, or use the library as a free-form study aid, selecting topics by choice or with instructor guidance. Students can view progress reports at any time, showing their effort level and the accuracy of their work (separated into multiple-choice and numerical components) as a function of time or by lecture topic or compared to peers. Personal, vocative feedback is also given after each quiz on a case-by-case basis.

The self-review library is implemented in dynamic HTML derived from an ASCII database on an Apache HTTP server. The HTML feature set is as conservative as possible, to allow for usage on both recent and outmoded versions of all three major operating systems and across a range of web browsers. Every effort has been made to keep data file sizes to a minimum to increase accessibility. The 12,000 questions and accompanying hints and solutions are stored in ASCII format and are supported by 11,000 figures averaging less than 15 Kb each in size. User names and access codes are stored in an encrypted format, and the back-end database controls have been written in Perl and C, optimized so that user requests take less than two seconds to fulfill.

2.2. The Instructor Interface

Instructors are provided with study records for both individual students and entire cohorts. Summary HTML-format tables present average scores per module topic for each student (and cohort averages) and weekly formal quiz scores, breaking down the results by question type and evaluating practice work and formal weekly quiz averages separately.

Instructors can click on the name of any student to review his or her work and receive student progress reports with several enhancements. Tables break down the average scores and number of questions by module topic and by week, accompanied by three overview figures with multiple indicators of progress and red flags indicating troubling events or trends.

Instructors are also provided with tables of all quizzes completed by each student, sorted by module or by date. The date and time are shown for each quiz, as is the amount of time spent. Each entry links to a complete quiz reconstruction showing submitted and correct answers, with links to hints and lecture web pages. These recreations can be very useful when meeting with students one-on-one. They enable the instructor to discuss the amount of studying being done and the timing of the work, and allow instructors and students to review each question and discuss appropriate study strategies. They allow instructors to show explicitly how the information in a hint can be used to answer a question, or to identify patterns of mistakes shown in student answers (such as repeatedly multiplying rather than dividing during units conversion).

A wealth of information is logged, allowing detailed analyses to be conducted on a variety of factors. Results are stored in an open format and can be analyzed with any tool (e.g., in a spreadsheet). Instructors can study the amount of time spent solving problems and reading solution sets, count the number of questions answered per topic or per unit time, plot the amount of practice done before each formal quiz versus scores on weekly formal quizzes, compare scores for self-review and exam questions by topic, and track progress over time on a topic for individuals or for a cohort. They can also "invert the analysis" and evaluate library questions, comparing success rates for different questions (or sets) or for a question answered at different times (e.g., at the start, after studying a particular topic for an hour, or after an in-class demonstration occurs).

Instructor reports are compiled once every 24 hours so that instructors can download a new cohort report on a daily basis. They are provided as encrypted files (using the PGP standard) transferred via secure file transfer protocol (sftp). Each report is distributed as an encrypted, compressed archive file that expands into a directory of HTML files conveniently navigated with any web browser.

2.3. Pilot Usage Studies in Classroom and Distance Education Mode

To test the usage of GEAS materials on-site versus in distance education settings, a GEAS-driven general education astronomy course was taught by the same instructor in both modes. An identical 88% of the two-hour final exam was used for both cohorts. The distance learning cohort scored significantly better (88.2% ± 7.6% versus 76.6% ± 12.3%), with a mean value one pooled standard deviation above that for the in-class students. A two-sample t-test yields a less than 2% probability that the two scores were drawn from the same parent sample. While more study is needed, this promising initial result suggests that distance education students may learn as much in physical science courses as in-class students when given resources that can be utilized appropriately by individuals working alone and at a distance from instructors and peers.

2.4. Collaborative Usage (Join Us!)

There are four primary modes in which the self-review library is designed to be used:

Sixteen-Week Class Sequence: The first mode applies to a class of students working through a 16-week timeline. Students use the practice and the formal weekly quiz tools and study all 26 lecture modules. This model works well for new faculty who have not yet invested significant time in developing their own lecture sequences who opt to work entirely from these astronomical modules.

General Study Tool: The second mode applies to a class of students working on an independent timeline, covering a subset of the 26 modules in any order. These students select sequences of modules to study based on their instructor's preferences and utilize the library as a personal study tool and to gain extra experience in working problems. This model works well for faculty with existing materials of their own who wish to provide addition problem-solving experience to their students and/or to satisfy certain state requirements for providing external activities for students.

Targeted Activity: The third mode applies to groups conducting a focused study of a particular topic within the self-review library. These individuals work within a "closed box" subset of the library. Progress reports and feedback forms are modified to reflect the short-term nature of the exercise. This model works well for studies evaluating the effect of new learning tutorials or aids.

Infrastructure Adaptation: The fourth mode applies to instructors and developers interested in utilizing the framework of the self-review library to develop online tutorial offerings for other topics. The framework and interface controls of the library are cloned, and a parallel, independent archive is used to populate a self-review library for another field or topic of study.

Collaborators are currently being solicited for all four modes, and inquiries from instructors interested in working with our materials in the classroom and for distance education classes are welcome. Individual test accounts in the self-review library are also available by request.[1]

3. Laboratory Exercises

A complete description of the astronomy laboratory exercie program is described by Vogt et al. (2013). The sixteen-week sequence covers topics in solar system, stellar, and extragalactic astronomy. Exercises include both hands-on experiments in which students construct tools such as sextants and transits, and use them to perform direct experiments and data-driven projects where students analyze recent astronomical images and spectra of planetary surfaces, stars, and galaxies.

4. Outreach Films

A complete description of our outreach film series, including download access, is available through the GEAS website.[2] Discussion guides are available to promote thoughtful classroom usage.

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[1]More information on the GEAS project may be found at `http://astronomy.nmsu.edu/geas`, or by contacting `geas@astronomy.nmsu.edu`

[2]`http://astronomy.nmsu.edu/geas/oview/films.shtml`

References

Vogt, N. P., Cook, S. P., & Smith Muise, A. 2013, "A New Resource for College Distance Education Astronomy Laboratory Exercises," American Journal of Distance Education, 27, 189