Astronomical Experiential Education Research Course

ASTR 299, Astronomy Research, Cuesta College, CRN 33248, Genet

Course Overview

ASTR 299, Astronomy Research, Cuesta College, CRN 32248, is being offered by Cuesta College as a one semester-hour course. Registration for the course opens on December 9, 2014, while the course will begin on Tuesday, January 20th.

This experiential learning course will introduce advanced high school and undergraduate students to scientific research. Although the specific research area is visual double stars, the lessons learned in planning a research project, writing a research proposal, gathering and analyzing observational data, drawing conclusions, and presenting the research results in a published paper and public PowerPoint presentation, are generally applicable to all areas of scientific research and, to some extent, to all other projects. For students planning on graduate school, this course introduces them to research and reporting on their research, preparing them for their Master’s thesis and doctoral dissertation.

The research teams are in-person and meet locally at various participating schools (often more than one team at a school), while the course overall is online. The course is structured as the Astronomical Experiential Education Research Institute. Organizing the class as a research institute provides a setting within which most research is actually conducted. The individual teams are remotely located branches of the institute. The institute’s director is the course instructor. Each team meets locally to conduct their research together as a team. All the teams come together synchronously online with the institute’s director for initial instruction, institute-wide staff meetings, and a final symposium.

The course is technology-enhanced in that the modern tools of scientific research are integral to the course including: online coordination of several teams located across the nation; the use of remote, automated research instruments (telescopes); extensive online conferencing; use of sophisticated reduction software; publication of results in online scientific journals; and PowerPoint presentations at online, conferences. Astronomical research has been a technology-enhanced activity for many years, with automatic telescopes at remote, mountaintop robotic observatories remotely accessed by astronomers for some three decades.

While the in-person version of this course has been very effective and successful, this new version of the course is somewhat experimental in that we honestly do not know how effective this approach of students learning about science by planning and conducting research themselves in widely dispersed teams will be. Will their skills in planning, team participation, concise writing, and public presentation be enhanced? Will today’s students naturally “take” to this modern, computer and on-line intensive way of doing research? As published scientists, will their motivation to enter STEM fields be increased?

This course provides an in-depth exposure to one area of scientific research—visual double stars. This in-depth, purposely narrow focus allows students in a single semester to reach the cutting edge of research in this field, meet many of the researchers, and experience what it is like to be on the frontier where the “answers” are not known. Once a student engages in actual research at any cutting edge, much of what they learn is applicable to reaching the frontier in another field. Once you have been there you know what it is like (and may not settle for anything less).

Research opportunities and observational techniques are covered in the course in detail. A significant portion of the course is occupied with writing and, after external reviews, perfecting a scientific paper that will be submitted for publication by the end of the course. Students learn that critical reviewers are their friends. While there is considerable individual learning involved, the research itself is conducted by student teams. All students end the course as coauthors of a published scientific
paper—an accomplishment that can provide a boost to their educational careers when it comes to scholarships, applications to graduate school, etc.

**Summary Learning Outcomes**

By the end of the course, students will be able to:

- Articulate the overall nature of scientific and astronomical research, describe the areas of double star research that are amenable to student observations, and explain the basic techniques used to quantitatively measure and analyze double stars.
- Plan and manage a research project, including writing a research project proposal.
- Be an effective leader or member of a research team.
- Calibrate and analyze astronomical observations.
- Plan, write, and critique a carefully-worded scientific paper.
- Prepare and present a concise scientific talk.

**Background**

Scientific research by undergraduate students has long been recognized as the capstone to their foundational science lecture and laboratory classes where, beyond mastering the known, the students launch into the unknown—science’s true home. They learn how science really works by being scientists themselves, albeit by way of modest-scale research projects.

Many undergraduate students learn how scientific research is conducted by participating as understudies in a research project managed by a faculty member. This is an excellent, time-honored way for students to “learn the ropes” of scientific research.

In this course, taking a somewhat different approach, student teams define and manage their own research. This is how scientific research teams normally operate at research institutes in academia, government, and industry. To fully capture this reality, the course has been structured as a research institute, the Astronomical Experiential Education Research Institute. The students are the research scientists in this institute, while the course instructor is the institute’s director. The tightly focused goal of this institute is to produce high quality published scientific research within the time and resource constraints of the course. The institute’s motto is “learn science by doing science.”

*Cuesta College’s in-person astronomical research seminar (ASTR 299) has been taught for eight years. Most of the students have been high school advanced placement students taking the research seminar on the side as their first college course. Being published scientists has helped them obtain entry into choice colleges, often with scholarships.*

For the past eight years, ASTR 299 has been taught as an in-person, one-semester, student-team-centered undergraduate astronomy research course every fall at Cuesta College on California’s central
coast. From the outset, the course was envisioned as providing a genuine research experience that was as similar as possible to what career PhD researchers would encounter while working at research institutes. While the scope of the course’s research projects were necessarily limited to match the one-semester time frame and student skills, all the normal rules of scientific research were applied, including working together as a team, mandatory publication, and presentation of results.

A number of different areas of astronomical research were explored during these undergraduate research courses, including variable star photometry, photometry of exoplanet transits, and double star astrometry. Double star astrometry was found to be particularly well-suited to one-semester undergraduate research courses, thanks to the relative ease of obtaining the observational data, analysis of the results, and prompt publication in the Journal of Double Star Observations or the Proceedings of the Society for Astronomical Sciences.

For many years these in-person research classes used low cost visual astrometric eyepieces and amateur astronomer’s telescopes—eyeballs to the eyepieces—to observe relatively bright and wide double stars. While such observations are continuing, more recent in-person classes have added the use of electronic cameras and, on occasion, observations with larger, remotely located telescopes.

![Image of Eric Weise and Concordia University students](image)

Eric Weise (left) checks the high speed speckle interferometry camera on the back of the 0.5-meter telescope at Dave Rowe’s Pinto Valley Observatory in the Mojave Desert. Eric took Cuesta College’s astronomy research seminar as both a junior and senior at Arroyo Grande High School. He continued his double star research with a half-dozen papers and two co-edited books to his credit, and is now a dual physics-mathematics senior at the University of California, San Diego. Russ Genet, John Kenney, and two young Concordia University students (right) stand under the 2.1-meter telescope at Kitt Peak National Observatory. The speckle camera they brought to Kitt Peak as guest observers is dwarfed by this huge telescope.

Conventional CCD cameras have been used to accurately observe wider double stars such as common motion pairs and short-arc binaries, while high speed electron-multiplying CCD cameras (EMCCDs) have been used to observe gravitationally-bound double stars (known as binary stars) with very close components. Such close-component binaries, if they are not too far from Earth, have short orbital periods, making them of special scientific interest. With an EMCCD camera, typically, 1000 images are obtained in less than a minute. Each exposure is only 20 milli-seconds long, which “freezes out” normal atmospheric “seeing” fluctuations. The many images are then processed in Fourier space. This process, speckle interferometry, is a state-of-the-art observational technique that we have mastered and rendered student-friendly with carefully written instructions and easy-to-use reduction software developed by David Rowe.

Over the years, almost two hundred students have successfully completed this research seminar and its summer science camp and other derivatives. The students have been coauthors of dozens of
published papers. These papers have benefited the students in terms of career advancement through admissions to choice schools, obtaining scholarships, and enhancing their résumés.

For a number of years the research course was also conducted as an in-person summer workshop at the University of Oregon’s Pine Mountain Observatory. Students (and their teachers) from a number of high schools and undergraduate colleges attended these workshops.

Besides taking the astronomy research course, many students have attended and given talks at scientific conferences. A number of course students and graduates (left) attended the 2013 Maui Double Star Conference hosted by the University of Hawaii’s Institute for Astronomy. Bobby Johnson (right) and his team at Arroyo Grande High School (Cuesta College course) prepare their talk for this conference.

The student education panel at the Maui Double Star Conference consisted of (left to right): Kent Clark, Editor of the Journal of Double Star Observations; Bob Buchheim, representing the Society for Astronomical Sciences; Eric Weise; Vera Wallen, retired high school teacher, district superintendent, and volunteer English/grammar editor for dozens of student papers; Jolyon Johnson, course graduate with over two dozen double star papers to his credit, and now a high school science teacher; and Russ Genet. Bobby Johnson (right) presented his team’s research results at the conference. At 16, he was by far the youngest conferee.
Astronomical Experiential Education Research Course

The successful, in-person undergraduate research seminar has been restructured as a combination distance learning / team in-person, technology-enhanced astronomical research course. Professional astronomical research has increasingly been conducted online, as remote mountaintop telescopes and observatories have been automated and research teams have become international. Could undergraduate student astronomical research also move in this direction?

This research course is being offered initially in the spring semester (January through May of 2015) by Cuesta College, a two-year public community college in San Luis Obispo, California. It will then be offered in the summer of 2015 as an accelerated five-week online course by Concordia University Irvine, a four-year private university in Irvine, California. Based on the experience gained at these two, quite different undergraduate institutions, the course will be expanded to other undergraduate schools.

During the course, the students will learn about scientific and astronomical research in general and double star research in particular. They will plan a time-and-resource-constrained research project which they will submit as a formal research proposal. They will then conduct their research following their written plan, culminating in a written and thoroughly externally reviewed scientific paper submitted to the Journal of Double Star Observations or the Proceedings of the Society for Astronomical Sciences for publication. Finally, they will prepare and present their results at an on-line scientific symposium and, for some (optional), at the annual symposium of the Society for Astronomical Sciences in Ontario, California.

The focused goal of the course—and the Astronomical Experiential Education Research Institute—is to produce high quality published and publicly presented research. The normal research institute tools for reaching this goal will be applied, including weekly staff meetings and refereeing of papers by outside experts prior to submission for publication. While this course, similar to its in-person counterpart, will concentrate on double star astrometry, student teams are welcome to conduct research in other areas of double star research, including photometry of eclipsing binaries, spectroscopy of double stars, and lunar occultations of double stars.

The Astronomical Experiential Education Research Institute

The class is structured as the Astronomical Experiential Education Research Institute. Organizing the course as a research institute provides a setting similar the setting for most real-world research. While the overall institute is online, the individual research teams are local and in person. We anticipate that this hybrid approach will combine some the best features of both in-person and online learning.

The Institute is organized as follows:

Institute Director

The Institute’s Director is the course instructor. It is the responsibility of the Institute’s Director to maintain high standards for both the quality and scientific pertinence of the research. Even though of modest scope, student research needs to be of significant value to the scientific community. The Director will only approve research project proposals that meet the institute’s standards and are clearly within the capabilities of the team members and time constraints of the course. The Director will provide guidance by way of periodic, institute-wide staff meetings throughout the entire process of proposal preparation, research project implementation, and the publication and presentation of research results, and will facilitate external review of research papers by experts prior to submission for publication and make certain that all research is published.
Institute Branch Chiefs

The Institute’s Branch Chiefs are Assistant Instructors that provide overall organization, supervision, and evaluation at each of the Institute’s participating schools. Typically Institute Branch Chiefs will retain their position over several years and will be active in recruiting new students to the course at their school.

The various Branch Chiefs will work with the Institute’s Director, Volunteer Assistants, and External Reviewers to maintain and refine the experiential learning environment for the students as well as assuring that research results are of a high quality.

Team Leaders and Members

The team members are the course’s students. Each team will select a leader to coordinate the team’s activates. It should be noted that within the State of California, high school students allowed to enroll in community college courses. Since the team leader and team members will all be from the same school, they will meet in person for their project-level work sessions and reviews. Past experience suggests that two or three small teams (three to five students) at the same school provides an environment with mild competition and peer pressure similar to may research institutes.

Volunteer Assistants

Volunteer Assistants include team advisors who are subject matter experts (double star astronomy) that provide counseling to a team. Such subject matter experts may be professional astronomers, advanced amateur astronomers, or former students who have continued their research after course graduation. Counseling will be provided online or by way of telephone conference calls.

An Editor will check all research papers for grammar, spelling, and other errors before they are sent to expert reviewers outside of the institute or to journal editors for consideration.

External Reviewers

External Reviewers are subject matter experts who provide written critiques of papers at the request of the Institute’s Director. A cadre of critical yet student-friendly experts has been built up over the years to provide prompt reviews of student papers.