

A Community - Centered Astronomy Research Program

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Abstract

The Boyce Research Initiatives and Education Foundation (BRIEF) is providing semester-long, hands-on, astronomy research experiences for students of all ages that results in their publishing peer-reviewed papers. The course in astronomy and double star research has evolved from a face-to-face learning experience with two instructors to an online – hybrid course that simultaneously supports classroom instruction at a variety of schools in the San Diego area. Currently, there are over 65 students enrolled in three community colleges, seven high schools, and one university as well as individual adult learners. Instructional experience, courseware, and supporting systems were developed and refined through experience gained in classroom settings from 2014 through 2016. Topics of instruction include Kepler's Laws, basic astrometry, properties of light, CCD imaging, use of filters for varying stellar spectral types, and how to perform research, scientific writing, and proposal preparation. Volunteer instructors were trained by taking the course and producing their own research papers. An expanded program was launched in the fall semester of 2016. Twelve papers from seven schools were produced; eight have been accepted for publication by the *Journal of Double Observations (JDSO)* and the remainder are in peer review. Three additional papers have been accepted by the *JDSO* and two more are in process papers. Three college professors and five advanced amateur astronomers are now qualified volunteer instructors. Supporting tools are provided by a BRIEF server and other online services. The server-based tools range from Microsoft Office and planetarium software to top-notch imaging programs and computational software for data reduction for each student team. Observations are performed by robotic telescopes worldwide supported by BRIEF. With this success, student demand has increased significantly. Many of the graduates of the first semester course wanted to expand their astronomy knowledge and experience. To answer this demand, BRIEF is developing additional astronomy research courses with partners in advanced astrometry, photometry, and exoplanets. The program provides a significant opportunity for schools, teachers, and advanced amateur astronomers to introduce high school and college students to astronomy, science, and STEM careers.

1. Introduction

The astronomy research seminar concept impressed the authors when they were first introduced to it by Russ Genet in 2014. Essentially the idea is to teach science by doing science as evidenced by the students publishing a peer reviewed paper based on their research (Genet et al. 2016). Research in astronomy is the means to introduce students to science and research as an exemplar of a STEM career.

The authors worked with Genet to introduce the classroom based seminar to San Diego from mid-2014 through mid – 2016. Based on this experience the authors created a new version of the seminar under their non-profit foundation, Boyce Research Initiatives and Education Foundation (BRIEF), and introduced it in the fall of 2016. The new seminar (now called “Double STARS”) was initiated for 4

high schools, 2 community colleges, and one hybrid online seminar for the fall semester of 2016. Forty-four students participated in 12 teams. Twelve papers were written and eight have been accepted for publication by the *Journal of Double Observations (JDSO)* as of April, 2017; the remaining four are in varying stages of review. In addition, five other papers were produced in the fall of 2016 and three have been accepted for publication.

The new “Double STAR” (STEM Through Astronomy Research for Students) course uses open source and relatively inexpensive tools to deliver content over the internet. The content and tools support classroom setting instruction at high school and community colleges and are also the basis for the hybrid in-person/online seminar. The new seminar is available to students of all ages, school enrollment, and financial means. The founders’ mission is to develop the program within the greater San Diego

area to enable student team interaction and to develop a community-of-practice for the students to engage in easily (Wenger 1999). BRIEF has placed emphasis on the San Diego geographic area for this community-of- practice to limit logistical issues but

more importantly to encourage the social interactions for students with the astronomy community. The learning objectives and skills acquired are broad; the astronomy learned is narrow but deep in double stars. (Figure 1.)

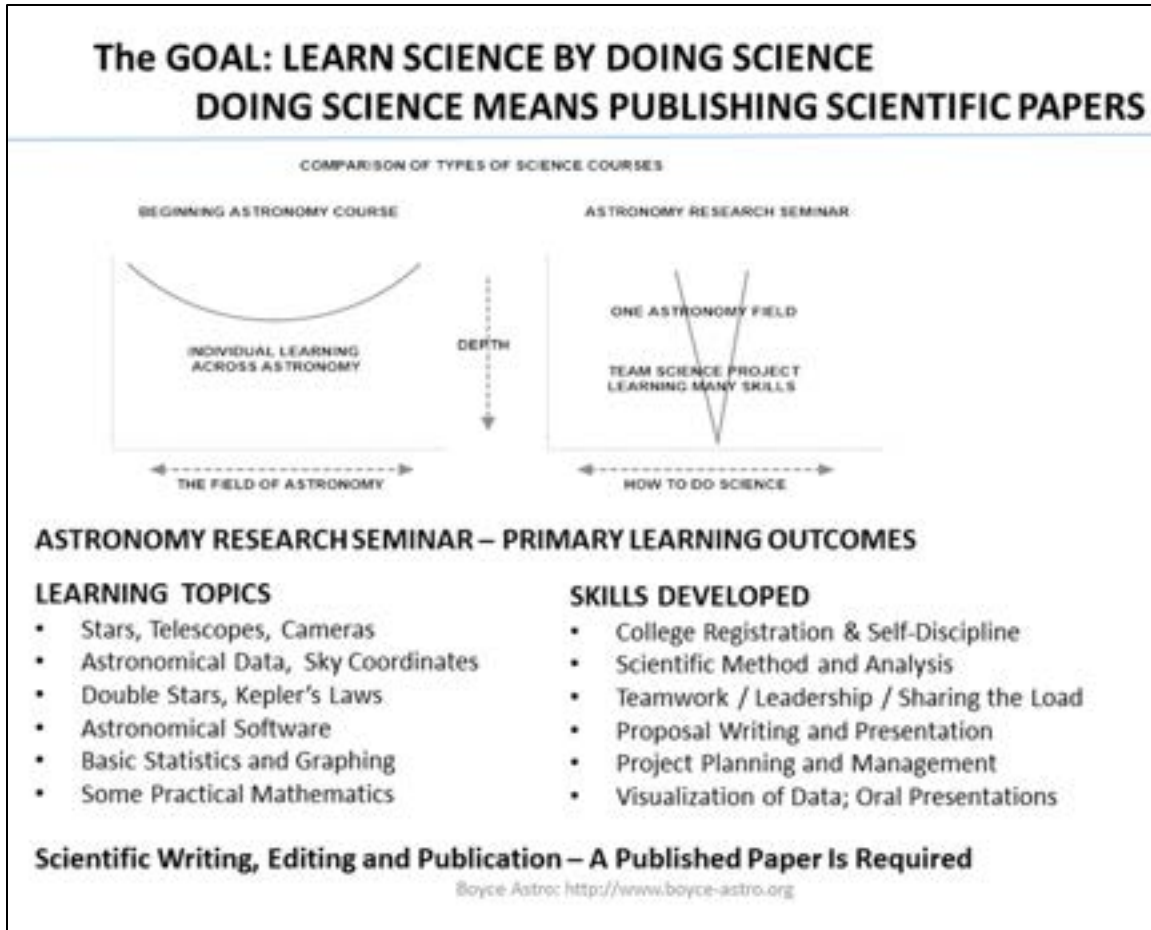


Figure 1. The learning objectives and skills acquired in the Astronomy Research Seminar.

Though initially offered as a one credit-hour community college credit course, experience has shown that this is not an important factor to many students who are interested in STEM careers. They see the experience and the recognition of being an author of a published scientific paper to be of greater value.

One measure of student acceptance so far: 50 % of the fall 2016 high school and online students enrolled in a new advanced, follow-on, not-for-credit seminar for the spring of 2017. This would seem to be a very high rate for volunteering to study further with no apparent reward other than self-satisfaction and the possibility of authoring another scientific report. This paper will describe the evolution of this STEM education program and the lessons learned

over the past three years. Student and instructor experiences and outcomes will be provided. The future development into a three semester program will be outlined.

2. Background

Pat and Grady Boyce founded the non-profit BRIEF in September, 2013 with the following mission as stated in its articles of incorporation:

“The specific public, charitable, scientific and educational purposes of this corporation are to provide scientific and technical research opportunities to enhance the educational experience

of students and to introduce them to the scientific and technical communities.”

An initial task was to acquire a modest observatory pad and RoboDome at the San Diego Astronomy Association (SDAA) site in east San Diego County, called Tierra del Sol (TDS), for education and outreach. The founders had already started an astronomy club at the Army Navy Academy (ANA) in Carlsbad, CA. This was shortly thereafter followed by their development and implementation of a University of California a-g accredited astronomy course that the founders then taught there for the 2014-2015 school year.

In the spring of 2014 the authors participated in an astronomy observation project at Kitt Peak National Observatory, met Genet, and learned of his research seminar. The authors introduced elements of the seminar in their ANA astronomy course in the fall

of 2014 using speckle interferometry data from the Kitt Peak observations. Four papers were published from this in the *Journal of Double Star Observations (JDSO)* in 2015.

For the spring semester of 2015, the authors started the astronomy research seminar at ANA as a once-a-week evening class (Johnson et al. 2015). It was offered as a remote extension, one-hour credit Cuesta College class. The authors course content was developed in parallel with teaching the class. Occasional videoconferencing was used and an attempt was made to provide a simple single seat server to host data reduction tools for the students’ data. A number of software problems and a lack of compatibility between client systems required spending significant instructional time on basic IT problems.

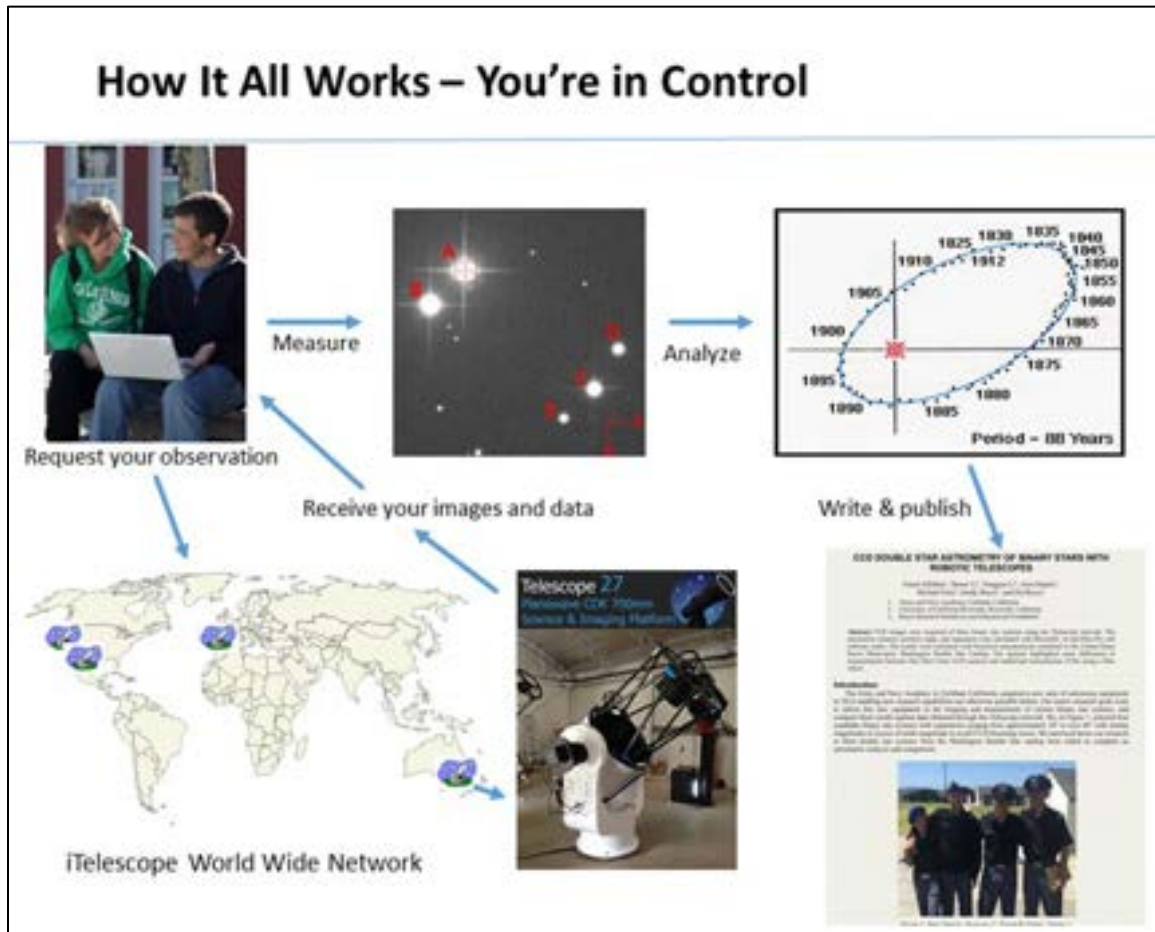


Figure 2. The Boyce-Astro student research workflow after the initial in depth instruction period.

Initial plans were to obtain double star observations locally, but seeing conditions on the coast of Southern California would not permit this in the short time period needed to complete the projects in one semester. To overcome this obstacle, the authors adopted iTelescope robotic observations paid by BRIEF using CCDs. Despite these difficulties 10 students participated in 3 teams to produce papers that were accepted for publication in the *JDSO*. The essential flow of the one-semester course using iTelescope stabilized. (Figure 2.)

By the fall of 2015, the seminar had settled on two basic software tools purchased by BRIEF: Maxim DL with Pinpoint Astrometry for plate solving and Mira Pro x64 for the astrometric measurements of position angle and separation of the double star images. However, the basic client compatibility problems of having students using a wide variety of platforms such as Windows-based computers, Apple based laptops and iPads, and iPhones and Android devices to process their data and collaborate on their presentations and papers still existed. Additional content was developed; refining the course with each semester. Having established an “alumni” base by this time, five students who passed the spring course returned despite not being able to receive another college credit for “taking the course again”. This was the first sign that the experience and the authorship recognition were more important than receiving college credit. (Figure 3.)



Figure 3. Army Navy Academy students were recognized at an SDAA meeting for publishing their papers.

For the 2015-2016 school year, the authors continued to teach the research seminar in the evenings but passed the teaching of the a-g astronomy class at ANA on to a physics teacher. It became more difficult to be a recognized program and be integrated into the boarding school’s after school programs. Though the seminar was strongly supported by the administration, classroom time was slowly eroded by other evening programs. Additionally, the enrollment process with Cuesta College remained difficult, taking many weeks and many steps for a student to register, with much time required from the authors. Signs were emerging that the complicated and frustrating registration process was beginning to dampen the student interest and enjoyment. The rising demand for the seminar outside of ANA required time to make the program available to a greater metropolitan area. The founders reluctantly passed the instruction for the ANA seminar back to the school in the spring of 2016.

3. Initial Lessons Learned

The founders compiled many lessons learned from their first two years of experience. Double star astrometry was confirmed to be a sound topic area for an initial STEM experience, introduction and completion of scientific authorship, and understanding as to the style and structure of scientific papers. Making observations in a short two to three-week period of time could only be done reliably with a network of telescopes such as iTelescope’s system to assure the seeing conditions and minimize any weather-related issues. Also, using robotic telescopes avoided the need to commit multiple long evenings for student observations – an almost impossible time commitment for most students. Training student teams to collaborate using a variety of PC, MAC, and other platforms can greatly detract from the intended learning experience and consume unnecessary hours of class time.

The course syllabus, first outlined during the ANA experience, evolved considerably from the initial half semester Cuesta design to a full semester class that incorporated much more of the content that the students wanted in astronomy and their research experience. The initial use of lecture and classroom recorded videos had to be replaced with self-paced learning modules for independent study so that classroom time could be devoted to questions and teamwork. Compelling research team development early in the semester had to be fostered and can be difficult. Instructor load could be substantially

reduced with the correct instructional materials, delivery methods, and supporting systems. (Table 1.)

Week	Topics	Activity
0	Introduction & Logistics & Teams	Meet fellow students
1	Double Stars, Kepler's Laws, Star Colors and Magnitudes	Establish Team Roles
2	Astrometry Fundamentals, Sky Coordinates	Begin coordinating as a team
3	Washington Double Star Catalog, How to access data	Begin selecting candidate stars
4	Online catalogs, Organizing data, Visualizing data	Request data from US Naval Observatory
5	Telescopes, Cameras, Filters, Imaging, Ordering Images	Begin drafting proposal
6	Planning research, Objectives, Schedules, Proposals	Finish proposal; Proposal Presentations
7	Review star images, Calibrating Images	Order images
8	Data reduction, measuring images	Send data to instructor for review
9	Statistics	Draft results of measurements and graph
10	Draft #1	Prepare and submit Draft #1
11	Review Drafts	Address comments & suggestions
12	Draft #2; Discussion: What is Science?	Submit Draft #2
13	Prepare for final presentation	Draft final presentation
14	Review Draft #2 suggestions	Prepare Draft #3 if necessary
15	Prepare final team presentation: Discussion: What have you learned?	Submit final paper
16	Prepare final team presentation:	Give final team presentation

Table 1. The Boyce-Astro first semester astronomy research seminar syllabus summarized by week.

To date, students of all ages from 7th grade to retirees have successfully taken the seminar, worked in teams, and a large fraction has continued on to other research topics. The mathematics required could be mastered but the writing and editing skills needed were the greatest challenges for the students. Educators and administrators can fail to realize that the seminar is a capstone learning opportunity that applies equally to science and liberal arts students. Just as Astronomy involves multiple disciplines, this course draws from many aspects of students' educational backgrounds culminating in publication. (Figure 4.)

For high schools, the seminar fits an after-school program, not a five-day-a-week class. To be sustainable at a high school it needs to have the same status as other after-school programs such as sports, drama or band. That provides the framework to fit it into the school's administration and operations. The seminar well suits a college curriculum which can be attended by students of all ages. On the other hand, not many high school students or adults are able to attend a college class during the daytime, and evening classes requiring driving can be difficult for many to attend as well.



Figure 4. Mount Everest Academy students proudly receiving their "diplomas" for completing the first semester seminar; the team members ranged from 8th grade to retirees.

4. The New First Semester Seminar (Double STARS)

From these lessons the authors developed a new and expanded seminar for launch in the fall of 2016 in the San Diego area. Instructors were solicited and trained from the community college ranks and from the seminar pro-am astronomy community well

represented by the San Diego Astronomy Association (SDAA) which has over 500 members. SDAA is over 50 years old, has a large observing site east of San Diego with public and private observing pads over a dozen observatories. The goal was to enable offering an adaptable seminar in multiple schools with differing venues and at different times rather than being limited to the span of time available to the authors alone. To enable this goal, new instructors not only needed to be trained, they also needed course content and support which BRIEF could provide. For efficiency, a common set of materials and systems were developed that could be used universally for classroom instruction in high schools and colleges as well as an online course. (Figure 5.)



Figure 5. Instructors posed for a photograph at a break in their training session in May, 2016.

The online venue is especially important to reach students throughout the San Diego area who are of varying backgrounds and means do not have access to a high school or college offering the seminar, or do not have transportation to brick and mortar venues. From an institutional perspective, due to many impediments in adopting new courses in most public institutions, the online seminar provides a path to institutional integration. San Diego spans a wide geographic area. The online seminar can easily reach and support the widely separated schools, many of which cannot devote resources to such a seminar. From a community perspective, the online course is especially useful and important for the underrepresented communities. The online seminar is a testing ground for content and systems to be used in the classroom instruction in the area's community colleges and high schools.

To increase instructors of the course, the authors' materials were converted to online self-paced video lessons with quizzes that were platform independent and could be accessed by students regardless of school venue. An online forum was established to provide supporting materials and support dialogue

between teachers and students in each school. Administrative tools to handle registration, recording keeping, and student text notices and reminders were established using commonly available tools.

Most significantly BRIEF acquired a dedicated five-seat online server called Boyce-Astro Research Computer (BARC) with all the software tools needed by the students to perform and write their research papers. Among the packages included initially were the SkyX, MaximDL, Mirametrics Pro x64, Reduc, as well as a full suite of Microsoft Office products. Because BARC can be accessed by all common PC, MAC, tablet, and other client platforms, the time previously lost by students and instructors solving software compatibility problems was almost eliminated. Self-paced learning modules could be tailored to the exact same screens and experiences all students would have in common. The file systems were established to provide various levels of permission by student, instructor, mentors, and administrators.

Use of iTelescope for double star observations for the classes continues to be an efficient and reliable source of image data with many systems available around the world. iTelescope handles the initial data reduction – flat fielding and subtracting darks from the raw images – so that students are not required to learn these details in these initial experiences. This in turn stream lines the process even more. The pricing for short exposure double star astrometry observations on iTelescope is reasonable. BRIEF continued its educator discount program to provide the observations to students for free to date. The total minutes of time allotted to each team are sufficient for their project. Teams with especially interesting and well proposed projects are granted more minutes' time. Boyce-Astro schedules the images on iTelescope based on student requests and downloads the successful shots to the BARC server student folders for each team's access and data reduction. (Figure 6.)

A full semester syllabus is provided for use by all schools which can be readily adapted to individual school requirements. More stellar astronomy is taught in the first few weeks compared to the Cuesta College offering. This provides the students with more time to develop their own research proposal including selection of target stars and the rationale for their selection. Requiring students to select their targets compels them to apply what they have learned in their deep dive into the astrophysics and double star astrometry in the first few weeks of the course. The second half of the course focuses on writing.

Each student team is required to present their proposed research to all their peers and all instructors in a San Diego area conference at the eight-week

mark. They learn that real scientific research as well as other endeavors is typically competitive and funded by well-developed proposals. At this presentation, they have to defend their proposal and as a byproduct they learn much from observing the other team presentations. It is a bonding experience

for each team and is increasingly an opportunity for the broader San Diego community to participate. The best proposals are awarded additional observation time.

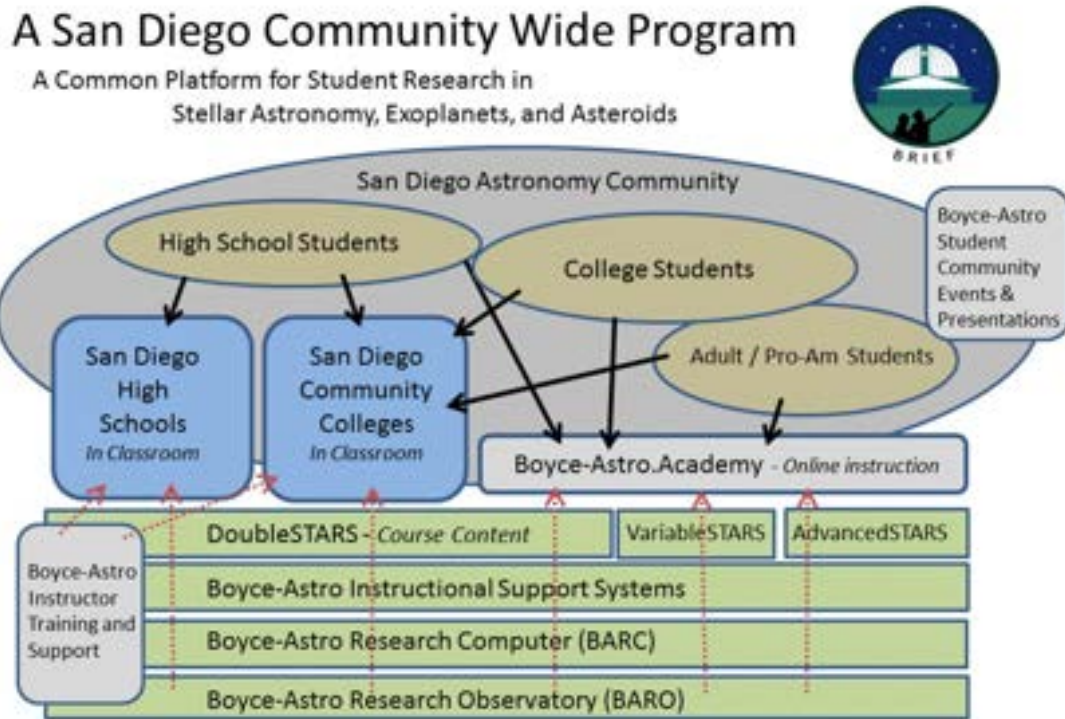


Figure 6. BRIEF's common community-wide instructional platform for the San Diego region.

Multiple observations are required typically over at least two nights and preferably from different telescopes. This introduces students to statistics and measurement of uncertainty. Then students are challenged to present their information graphically and hypothesize the possible alternative meanings of their results with special attention given to understanding outliers and the quality of the various past observations.

The semester culminates with a final presentation by each team, again in a community wide setting in a public library. Friendly but thoughtful criticism is offered by the instructor group as well as the students. At this stage, all teams are expected to have been through at least their third draft review by their instructors. The PowerPoint presentations provide useful feedback on their

methodology, results and conclusions which can be incorporated into their final paper revisions. (Figure 7.)

5. New Lessons Learned

After conducting the new seminar for nearly two semesters in its various venues, a new set of lessons learned can be summarized.



Figure 7. Final presentation day at a public library. All San Diego teams meet to present their research to each other, the instructors and interested members of the community.

5.1 Overall Systems

In general, the new seminar has fared well, and evolved, through student and instructor evaluations. Self-paced learning units' using EdPuzzle are very well received by students and have reduced the instructor workload considerably. The text messaging system (Remind.com) is essential as most students do not read their email very often. Students did not use the online forum for discussion and would be better served for team collaboration through Google Hangouts or a similar free tool. The resource content on the forums will be moved to BARC which should simplify student interaction as well as administrative burden. Eventbrite has sufficed for online registration but a data management add-on will be added to simplify the enrollment process further in the future. In aggregate, the systems are an inexpensive, flexible and adequate alternatives for the current level of operations compared to the more cumbersome instructional systems such as Canvas and Blackboard mandated by various school systems.

BARC has overcome the compatibility and data management problems experienced in the past despite initial challenges in administering the server security protocols. To allow individual instructor software preferences and more research options, the BARC software suite has been expanded to include DS9, AstroimageJ, Stellarium, Sky Tools, Speckle Tool Box, and Astrometrica. iTelescope has continued to work well for the short exposure observations needed for double star astrometry. Still the administration of BARC and the observation management with iTelescope are time consuming even at the current levels and support staffing through student interns is being considered for the future.

5.2 First semester seminar syllabus and content

Students and instructors have been solicited for critical comments regarding the course content and methods. The replies especially from students were highly favorable. Considering where the seminars began in early 2015, the suggestions are really refinements.

When asked, the two most common suggestions are 1) to provide more time and guidance in target star selection, and 2) to provide a single consistent formatting guide for the papers. For the first the class segments describing the nature of science will be moved to the end of the semester for the point in time when students can appreciate the scientific research they have done. Enhanced guidance in paper formatting consistent with other astronomy journals and the JDSO, will be addressed with an updated "Elements of a Scientific Paper" handout as the sole guide. The BRIEF Advisory Board recommended adding basic photometric measurements to the astrometric data reduction now done and encouraging more historical research in the proposal phase. They recommended assessing individual student performance and their team contributions through final interviews. Some instructors experienced difficulty in establishing research teams and would appreciate receiving more guidance. All participants recommend even more training in writing – a common problem for all the past seminars that has proven difficult to fully resolve.

5.3 Experiences by Venue

Two high schools, Mount Everest Academy and the Cambridge School, were able to host the classroom seminar for students on their campuses, and Cambridge was able to include students from the nearby Westview High School. Professional-amateur ("pro-am") astronomer volunteers, Kent Smith and Allen Priest, were recruited from the ranks of the SDAA. They conducted the classroom instruction with occasional in person support from the developers. Both instructors performed admirably, and Kent Smith was even able to have all four of his team papers accepted for publication by the end of the semester. They were not able make this level of time commitment for the spring semester and there were no other trained instructors available to continue the high school classroom instruction in the second semester. Students ranged from junior high age to high school and community college instructors. High school teachers were not available as instructors, the reasons for which will be described later.

Two community colleges, Grossmont and Miramar Colleges, utilized the new Boyce Astro seminar content and support as the basis for honors “contracts” for interested science students. There is no course equivalent to Cuesta College’s ASTR 299 one-hour credit course at their or other California Community Colleges. The honors contract approach allowed students to gain the added benefit of an honors class credit for the extra work and minimized the volunteer time commitment for the instructors. [See further discussion of these constraints later.] Both Jae Calanog at Miramar College and Sebastien Cormier at Grossmont College were able to continue their volunteer honors course instruction in the spring semester and Irena Stojimirovic was able to create a similar and larger honors program at Mesa College. All three instructors use the Boyce Astro content, BARC server and robotic telescope accounts to supplement their guidance and they collaborate with each other for added content and student support. Students enrolled at the community college seminars grew from 17 in the fall to 25 in the spring.

The hybrid online seminar conducted by the authors had 5 students in the fall semester and 26 students in the spring of 2017. It is called “hybrid” in that weekly online synchronous meetings (content is always available by asynchronous means) and at least two community-wide meetings are held each semester. Zoom, an online videoconferencing system, is the primary tool for online classes, whiteboard discussions and class discussions. These sessions are recorded so that students could return for review or do a makeup if absent. A second online seminar, Advanced Astrometry, was added for fall graduates and 13 students registered for it.

Fall students in the hybrid online seminar ranged from high school age to college graduates, including one high school teacher. The spring first semester hybrid online seminar grew five-fold for these reasons: no high school classroom instruction available and a new relationship with BEWiSE, a San Diego initiative that encourages young women (7th to 12th graders) to enter STEM careers. The BEWiSE group (Better Education for Women in Science and Engineering) epitomizes the power of the online course to reach underrepresented communities regardless of their school’s ability to participate. Another paper will address the significance of this and how it can apply to other communities. (Figure 8.) A further student addition came from astronomy students at San Diego State University (SDSU) who wanted research publication experience and authorship that is not available at the University for undergraduates.



Figure 8. A screen shot of the online class in the spring of 2017; the course had more young women than young men thanks to BEWiSE support.

Of the 26 spring semester high school students 18 initially expressed interest in taking the course for one-hour college credit through Cuesta College; only 3 made it through the excruciating administrative hurdles to be registered. The rest were content to take the course for the experience and the value of authorship for their scholarship and college applications. After the above referenced registration difficulty, Cuesta had a change of policy and would only admit students if they joined their Canvas based online classes. When given the choice, all of the registered students chose to withdraw from Cuesta and remain with Boyce Astro even though they would not receive college credit through the Boyce Astro seminar. This is both an indication of the perceived value of the Boyce Astro online course and an expression of the power of community for student participation.

The proposal presentation and final presentation meetings have been held at public libraries with all students, instructors from all schools; other interested parties such as parents are encouraged to attend. In each instance the students have expressed a renewed vigor after seeing their peer’s presentations. There is healthy competition between the teams.

6. Next Steps

The revised seminar program can be sustained at its current level as long as instructors from of the three community colleges and two high schools continue to volunteer their time. BRIEF is able to financially support the instructional systems, the BARC software and server, and the telescope resources required. The baseline hybrid-online course can be sustained as well at the thirty student level as well as provide the underlying school support. Thus the current capacity is approximately 60 to 75 students per 1st semester students enrolled in the fall

and the same in the spring assuming some efficiencies can be attained.

Based on the past years' experience, BRIEF will streamline some of the administrative systems and consolidate the Forums content onto the BARC server. A number of 1st semester graduates are continuing to participate in follow-on classes. An internship program will be attempted in the fall of 2017 to provide support to the principals so that they can undertake further program development while supporting the 1st semester classes.

A primary focus for the next school year will be to address the interests of the graduating 1st semester students who want to go further into observational astronomy. The following three semester series will be developed using the new course acronym STARS (**S**TEM **T**hrough **A**stronomy **R**esearch for **S**tudents)

- **Double STARS**: a refined version of the current 1st semester seminar
- **Variable STARS**: a seminar in both single image (UBVRI) and time series photometry
- **Advanced STARS**: guided independent research in stellar astronomy, exoplanets and asteroids

Rather than reinvent or compete with the excellent educational materials offered by the American Association of Variable Star Observers (AAVSO), BRIEF intends to make its Variable STARS seminar complement the courses offered by AAVSO. The Variable STARS course will focus on analysis and publication based on the variable star observation knowledge gained from the AAVSO CHOICE course. This collaborative project will begin in the summer of 2017 for a pilot seminar launch for the fall semester of 2017

A pilot seminar is currently underway for the Advanced STARS seminar with students who have completed the 1st semester binary star seminar. There was a strong demand for this course from the fall 2016 semester high school and online students. Projects are in astrometry, single image photometry, speckle interferometry, and exoplanet transit measurements.

The time series photometry and exoplanet observations needed for the new courses require long duration exposure sequences that are cost prohibitive using iTelescope. BRIEF has acquired a half time lease of an excellent 16" RC robotic telescope at the Sierra Remote Observatories (SRO) to support these long duration observations. In addition, BRIEF's own robotic observatory, the Boyce-Astro Research Observatory (BARO), is expected to come online initially with an 11" SCT in the summer of 2017

followed by a robotic 20" CDK. These will ultimately support CCD based astrometry and photometry and speckle interferometry. The San Diego Astronomy Association (SDAA) has offered student observation time to BRIEF on its Terry Arnold Robotic Observatory (TARO), a 14.5" fully robotic RC.

To tie the educational program and courses together, BRIEF is packaging the offering into an academy, Boyce-Astro.Academy, with a new website to integrate the instructional materials and support. The Academy will offer the three online non-credit courses listed above as well as continue to support the San Diego area classroom instruction at the community colleges and high schools that have trained instructors.

Boyce-Astro will continue its special projects, workshops and special events to encourage development of the San Diego area student, educator and pro-am astronomy community. For example, in October, 2016, Boyce-Astro offered a two-day exoplanet workshop taught by Dennis Conti of the AAVSO for San Diego area students and astronomers. In August, 2017, Boyce-Astro is manning one of the key observation sites for the total solar eclipse under the Citizen CATE (Continental-America Telescopic Eclipse) Experiment sponsored by several federal agencies (Penn 2015). The Boyce-Astro team is comprised of students, faculty, and pro-am astronomers from San Diego. For the 2018 Greater San Diego Science and Engineering Fair, Boyce-Astro will award a scholarship for a top-notch astronomy project as judged by the Instructional staff. The winner will be selected on the basis of the project that is most prepared for scientific publication. Boyce-Astro will continue to seek opportunities to collaborate with the SDAA and its membership to strengthen the San Diego astronomy research community. (Figure 9.)



Figure 9. BRIEF hosted a one-day workshop on small telescope research at the summer AAS conference in San Diego in 2016.

7. Further Growth

In March, 2017, possible future directions for the student research program were reviewed with BRIEF's Advisory Board. The Advisory Board is comprised of Russ Genet (Adjunct Professor at Cuesta College, and Research Scholar in Residence at California Polytechnic State University), Stella Kafka (Director, AAVSO Bob Buchheim (President, Society for Astronomical Sciences), Mike Chasin (President, SDAA), and Philip Blanco (Lecturer, Grossmont College). Based on this review the founders formulated the "baseline" plan above under "Next Steps".

The student potential in San Diego is many times greater than the 60 to 75 student level per semester in the baseline plan. The Advisory Board discussions centered on what would be required to raise the student enrollment to 250 or more students per year.

Despite the apparent student demand for the seminars, a number of factors constrain growth and can even affect the viability of the community-wide program. These need to be addressed if one is to expand the program substantially. Most could be overcome with additional financial support.

7.1 Constraints to Growth

The growth to higher levels of operations depends on the rate of growth possible given these known constraints and the availability and timing of resources to overcome them.

- **Instructor compensation and reward:** To date the seminars have been staffed by volunteer instructors and the time commitment needed is not inconsequential. Though the authors intend to continue their volunteer time contributions one cannot expect others to make this commitment on a sustainable basis.
- **Instructor training:** To extend the seminar beyond its current schools to provide a more stable base of operations requires additional instructors who will need to be trained. If modest compensation for instructors were available, the ranks could be filled. An instructional team comprised of a school science teacher and a pro-am astronomer is best. It's the rare science teacher who knows the details of conducting astronomical observations. The pro-am astronomer complements the teacher's instructional skills as well as the knowledge of school practices and operations.

The current instructor training of having a qualified science teacher or pro-am astronomer take the seminar themselves is necessary but not

sufficient. Knowledge of course systems and processes is needed as well which can be accomplished over a weekend workshop with reference materials. Taking the online seminar can then provide experience needed to lead a seminar.

- **Logistical support:** Course enrollment, systems administration (e.g. BARC) and observation management require time from the authors that can be accommodated at current operation levels, but additional support is needed if more schools and students are added. Student interns are the hoped-for solution in the near term but may not be a sustainable solution due to turnover in the long term.
- **Sufficient peer review resources:** Every paper requires considerable review and edit by the instructional staff. Despite this effort, the time required by the largely unrecognized peer reviewers is a significant time commitment for them. A broader pool of reviewers needs to be developed to assure adequate and timely review of all papers as produced.
- **Publication:** Almost all 1st semester papers have been published in the *Journal of Double Star Observations* (JDSO), an online peer-reviewed scientific journal. If for some reason the JDSO were to discontinue operations, the opportunity to publish papers in process at that time would be disrupted. If an alternate journal were not found, the basic premise of the course to publish a scientific paper would be seriously compromised.

School administrative regulations are significant barriers to grow operations rapidly even if the above constraints overcome. Here's a short digest of the factors:

- **High Schools:** A weekly seminar does not fit into a 5-day a week, two semester course, curriculum which is the mainstay of California qualified a-g courses needed for college admission. The seminar could be integrated into an existing qualified a-g course but that requires time and concerted effort from instructors and administration. The seminar can be offered as an after school program on a weekly basis substantially in its current form. Unions will not permit it to be offered on a volunteer uncompensated basis, so school or other funding is necessary to establish a recognized course or after school activity. At least for San Diego public schools, the internet security procedures require any accessible website or resource to be certified for student use. This impedes the use of the course materials and BARC to support the

seminar in the classroom or in after school programs.

- **Community Colleges:** The instructors are generally overloaded with classroom commitments and cannot take on a volunteer activity that is not recognized in their expected time commitments for teaching. Adequately attended and recognized courses do count though. For now, the seminar is used to create honors contracts which are recognized by the schools for students in science and other classes. It takes at least two years to get a new course such as the seminar through the curriculum adoption process. An effort has begun to gain approval for the seminar in the 2018 to 2019-time frame. In the interim the seminar instructors are volunteering their time as honors contract advisors.

7.2 A Possible Pathway

Community colleges are best suited to be the center piece of an expanded classroom program. High school, college and adult student communities are able to enroll in there with modest fees. The challenge is to establish a stand-alone (not honors) class in which all three student communities can enroll. A further enhancement would be to enable high school students to receive dual credit. Establishing such a class seems to be an arduous and slow process. Meanwhile students are having to be served by volunteers who are stretched for time.

A bridge financing until such time as the colleges adapt would put the program on sound footing and enable the growth to the higher level of operations. Such funding might be accomplished through a scholarship program or through direct contributions.

There is a new National Science Foundation (NSF) grant to California Polytechnic State University managed by Russ Genet (see Genet et al 2017). Its goal to evaluate the astronomy research seminar for broader implementation to other areas of science as well as to determine its STEM teaching effectiveness will span three years. It is expected that San Diego and the NSF grant team will share in lessons learned from the grant. BREIF intends to move San Diego forward at a possibly more rapid pace depending on resources and overcoming at least some of the constraints identified.

8. A Long Term Goal for San Diego STEM

With an expanded astronomy research seminar program, San Diego could become a national model for STEM education. If the resources were available to achieve the 250 student per year level of operations, triple the current level, the expanded STEM educational program through astronomy research for the San Diego area could look like this:

- **Community Colleges:** Four to six colleges conducting the first semester classroom seminar for two hours' credit with each school having 20 to 30 students; have cooperative programs in place with local high schools to encourage their students to attend the seminar at the community college
- **High Schools:** Four to six San Diego area public or private high schools conducting the classroom seminar with 15 to 25 students each; magnet schools for STEM would be the best candidates; the seminar could be integrated with their astronomy or physics a-g course or be offered as an after school program.
- **Online first semester seminar:** Boyce-Astro.Academy would conduct one first semester hybrid online seminar (Binary STARS) to address underrepresented communities and instructor training each semester. Additional online seminars could also be led by trained instructors too.
- **Online advanced seminars:** Boyce-Astro.Academy would conduct the Variable STARS and Advanced STARS seminars for graduates of the first semester seminars from the San Diego community colleges, high schools, and the Binary STARS seminar.
- **Community of Practice:** Expand the community-wide proposal and final presentation programs to accommodate the larger student population; added workshops and teaming projects to encourage independent student experimentation and research mentored by experts in the San Diego community; encourage participation by the university community.

The consequences of such an expanded program need to be understood in their entirety. For example, about 40 papers per year would be produced needing peer review and publication. The *JDSO* currently publishes between 10 and 20 papers per quarter. The San Diego papers would increase the peer review requirements as well as the *JDSO*'s content almost 40%. Other areas in California and Hawaii are also

ramping up. The total impact could be overwhelming for the *JDSO*.

The logistical support needed for the San Diego operations would require one to two full time staff members supported by interns. Server upgrades would be needed. BRIEF's projected telescope resources would, however, be adequate. An additional sustaining source of funding would be required to add these capabilities. On a cost per student basis, it would be inexpensive when compared to similar programs.

9. Initial Assessments

As the new seminar is in its second semester of operation, a formal evaluation is not possible yet. One measure of success with students is the number of fall 2016 first semester graduates who have chosen to take the Advanced Astrometry pilot seminar in the spring of 2017. Table 2 provides those figures for the high school classroom and online students. This course is not for credit. The community college students were not solicited for the second semester seminar; they have little time to take not-for-credit courses. Despite that a two are acting as voluntary mentors to first semester students now taking the seminar. In total 50 percent of the fall 2016 high school and online students chose to enroll in the not-for-credit second semester seminar.

9.1 Classroom Instructor Feedback

The seminar community college and high school instructors provided these comments to an informal survey recently conducted.

Does it encourage critical thinking?

"I believe that it does encourage critical thinking. The students were required to provide evidence for all claims they made in their papers. I remember drafts being sent back to students with the comments, "Can you back up this claim?" and "Can you provide evidence?" or "This sounds like opinion." I don't think the high school students had ever had to write a paper that required so much rigorous evidence before. It hopefully helped to stress the difference between fact and opinion. "

Fall 2016 First Semester High School & Online		Students Continuing for Advanced Astronomy
Class Venue	Students	
Mount Everest Academy	11	4
The Cambridge School	4	2
Westview High School	6	4
Boyce-Astro Online	5	3
Total	26	13

Table 2. Many first semester students wanted to continue research in the spring of 2017 with the Boyce-Astro pilot seminar in advanced astrometry.

"YES. ... the whole process encourages critical thinking! For example, when students are trying to choose a double star system to study, they're thinking about: "Should I pick a star that's well studied and have multiple publications OR should I pick a star that has few observations?" There's pros and cons to both but ultimately, they have to weigh out their options. During the observations, they have to think about the many factors to consider since they have limited resources (telescope time). Questions such as: When should we observe it? How can we figure out an exposure time that doesn't saturate our images? Which filters do we use?"

What impact does it have on STEM career decisions (increases or decreases interest or no impact) and what factors seemed to be most influential?

"...there are many STEM careers that have nothing whatsoever in common with writing scientific papers, but it's hard to avoid planning, project management, communicating, working with other people, or having to meet standards or expectations in the real world; all things that students were exposed to the seminar. Authoring a published scientific paper gave some students, I believe, the taste to do it again. "

"It's a bit hard to answer this question since this would only apply to students who weren't STEM to begin with. As far as I know, from Fall to Spring, I've

had one student who was not of STEM background who I know is still deciding. However, I have had conversations with my students who were already interested in STEM. They've mentioned that this seminar has only encouraged them and reinforced why they picked the right field to begin with. I'm guessing that's a good thing! “

“Some may not enjoy having their results criticized or put on public display. Others may totally enjoy the process of scientific discovery and really be fired up about it. ... Several of them loved the process and writing a scientific paper and will likely pursue a scientific course of study in the future.”

Though the course uses double star astrometry as a topic area, do the students see the methodology to apply to other areas of science?

“In the seminar the students had to learn first-hand about the difference between accuracy and precision; worked with statistics, uncertainty, and error analysis; experienced project planning; were required to clearly state goals, summarize work done, and--something I really thought was excellent--deal with conclusions that were not what they expected.”

“The students probably can't answer this right now because it's too early in their careers. Having gone through community college to a 4-year university to a PhD program, I can tell you that I definitely wish I had this experience early on! The methodology that we follow in writing the paper is the same methodology that I was introduced to not until graduate school! If these students continue to higher education, then I can only imagine that this experience will make their learning curve in research less steep.”

“I think they have a good handle of the use of the scientific method and how to go from a hypothesis all the way through to published work. I think they would definitely be able to apply this to other scientific fields and, in fact, I have seen some of them do that with science fair projects.”

How would you change it to enhance its impact on high school and community college students?

“I think community college students need to be informed and aware of the actual impact it can make on their careers... I think they also need to understand that this seminar is a professional development opportunity for them. They can use the seminar to write about their experiences in their college applications, ask me for a letter of recommendation, and also use it as a basis for applying for other internships.

Professional development opportunities is what I'd like to improve on to enhance its impact. For

example, workshops on how to make great presentations (I'm working on this one right now), great posters, incorporating the seminar in their resumes and personal statements, etc. would be extremely beneficial in helping our students reach their professional goals”

“I would bring in scientists/astronomers/academics and have them talk about what their everyday work is like. Also, I would consider adding a field trip to Palomar Observatory.”

Writing a peer-reviewed paper is almost always cited as the hardest part of the seminar. Instructors also noted these communication and social adjustments were challenges too:

“The seminar helped the high school students prepare for college by treating them like college students; for the first time, for many. One thing the students did in the seminar that they do not do in high school is interact with adults and experts who are not their "teachers," but mentors and peers.”

“I think they actually struggle with the presentation. Many of them can't communicate their ideas or generate interest in a public speaking setting.”

“I would also say communication, amongst each other and with me. They're still a bit culture shocked that the relationship between professor-student is different from advisor-student. I observe this during our meetings because sometimes they expect a lecture from me and everyone is really quiet, whereas it's actually the exact opposite.”

9.2 Quotes from students

High school and online students from the fall 2016 first semester were surveyed; in addition to their other replies, they provided these quotes:

8th grade student (who won second place in the California State Science Fair):

“The Astronomy 299 [previous designation] course was a great experience. I learned how to write a scientific paper about my own measurements double stars and get it published!”

High School Students:

“As a high school student with a passion for science and Astronomy, I feel so lucky to have the opportunity to research under the expert guidance and support of Boyce-Astro. Learning that my research will soon be published has been the highlight of my education so far and will add valuable substance to my college applications.”

“The Astronomy Research Seminar is a unique and enriching opportunity that allows students to participate in scientific research. Besides the incentive of becoming a published researcher (even

while in high school!), the program allows students to gain insight into how research is conducted and improve their teamwork, leadership skills, public speaking, presenting skills, and writing abilities. I would highly recommend this program to any students interested in science in general. Prior astronomy experience is not required to take advantage and benefit from this opportunity."

"The program taught me how to write an academic research paper - from conducting background research, to the proposal, to editing and submitting the paper. Furthermore, it helped me hone communication and organization skills through working and coordinating within a team setting, an aspect of utmost importance in STEM."

A Community College Student:

"Being a part of this research group really helped me in three areas of my life: gaining valuable research experience in the science field, learning how to work in a group setting, and networking with like-minded individuals."

Adult pro-am astronomer online student:

"This class solidified some astronomy concepts while introducing new ones. Grady makes it fun and accessible. Best of all, his relentlessly good attitude makes the challenges less daunting.

These initial student and teacher assessments, though only anecdotal, are encouraging. A further review and assessment is underway to identify enhancements to make in future semesters.

10. Conclusions

After three years of development the Boyce Research Initiatives and Education Foundation (BRIEF) has successfully launched a community wide astronomy research seminar to enhance STEM education in the San Diego area. BRIEF has established a common educational platform that serves high school and community college classroom instruction as well as hybrid online classes. The lessons learned and the model may be extensible to other communities to apply. BRIEF is proceeding with additional advanced hybrid online courses under its new Boyce-Astro.Academy and is committed to growing the San Diego area astronomy community.

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