George Ellery Hale Collaborative Graduate Education Program (CGEP) in Solar and Space Physics, 6 September 2013

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The relocation of the headquarters of the National Solar Observatory (NSO) to the University of Colorado (CU) campus has refocused our attention on how to meet the graduate educational needs of the solar and space physics community. The field is not unique in facing rapid cross-disciplinary development with important societal relevance within an increasingly resource constrained higher education environment. The education of the critical next generation of scientists, engineers, and leaders thus faces a fundamental structural challenge: how to provide highest quality graduate education spanning a wide range of expertise without undue duplication of faculty at multiple institutions.

There is a mismatch between the need for graduate level teaching in solar and space physics and the ability to meet that need at any single institution. The specialties making up the subject are quite broad and a sound education in the discipline requires graduate level instruction over the range of topics, but faculty and students are distributed across universities. Moreover, essential expertise also lies off university campuses at research labs and within industry. The teaching of graduate students entering the field within any given university could benefit from an approach that makes better use of these distributed skills. At the same time, Science, Technology, Engineering and Mathematics (STEM) teaching best practices, and more generally education research, emphasize the need for instruction to move away from a lecture format toward one that engages the students more fully in the educational process via inquiry based learning. A pure lecture environment is quite easy to distribute either synchronously or asynchronously over considerable distance, while more effective interactive instructional methods require some care. We aim to do both: bridge distributed institutions and provided highest quality education.

We have thus initiated a new collaborative approach to the teaching of graduate courses within the solar and space physics graduate programs at CU, the New Jersey Institute of Technology (NJIT), and the University of Hawaii (UH), with active participation by NSO and the High Altitude Observatory (HAO) scientists. We have completed the inaugural web-enabled class using the Cisco WebEx meeting environment, have had graduate student involvement in Professional Development and Research Experience for Undergraduate (REU) programs between campuses, and have initiated discussions to broaden participation to include New Mexico State (NMSU) and Montana State (MSU) Universities. In addition to successes, these preliminary efforts have raised a number of key issues and challenges.

First Efforts and Lessons:

The inaugural Collaborative Graduate Education Program (CGEP) class in solar and space physics was taught during the Spring 2013 academic term. The host site was the Department of Astrophysical and Planetary Sciences at CU, with the course titled “Solar and Stellar Magnetism,” and the class taught twice per week at 2:00 – 3:15pm MST, the time slot somewhat constrained by the time zones spanned by the participating institutions (with an 11:00am start time in Hawaii and 5:15pm end time in New Jersey). Small offsets in academic calendars were accommodated by the recording capabilities of the technology employed (below).

Participation in the course was excellent: CU (7), NJIT (10), HAO (5), NMSU (3), UH (2). At CU and NJIT enrollment was arranged via a Special or Advanced Topics course listing, allowing enrollment in future CGEP classes under the same course number. At UH and NMSU the course was audited (noncredit), and HAO participation was by postdoctoral fellows and staff scientists. In addition to the broad student participation, lectureship spanned a broad institutional range, delivered by scientists from CU (2), HAO (3), NSO (1), and the University of Wisconsin, Madison (1), with all lectures physically delivered from the host CU site.

The technology employed for this first course offering was Cisco's WebEx Premium meeting environment, which allows up to 25 participants, voice over Internet (VoIP) audio, desktop, document and application sharing, and 1 GB of storage for session recordings. This incurred a yearly service cost of $480. Set up of the lecture room at the CU host site involved the purchase of one high-resolution ceiling projector, a multi-angle screen, two remote zoom-steerable cameras with mikes/speakers (it would be preferable to have a better sound-suppressing conference mikes/speakers at a somewhat increased cost), a lectern, and two modern laptops, one for the presenter and the other for the meeting coordinator, the later responsible for driving the projector and controlling the second camera. Room incidental costs included tables, chairs, and ceiling spots. The total cost of the lecture room setup was about $7500. We also purchased headsets for all student participants but did not employ them much given vagaries of direct speaker voice and VoIP sound irregularities (below).

A number of key lessons were learned from the inaugural course:

- To facilitate learning, each satellite site should have a dedicated mentoring instructor. This person should be capable of filling in gaps in prerequisite knowledge, overseeing group activities and projects, and encouraging discussion. Prerequisite knowledge is of particular importance, as the goal of the CGEP is to provide in a distributed way the high level graduate courses that can not be routinely offered at any single participating university, but each participating graduate program has a different core curriculum upon which these courses build. Significant future effort must be invested in an agreed course listing, the individual course contents, and course problem sets and projects. All of these must be tailored to the participating graduate programs with "ownership" and responsibility for individual courses distributed among individual faculty.
- The Cisco WebEx Premium technology did some things well, and others not so well. It was particularly good at high-resolution sharing of lecture slides and the recording of lectures. It was less well suited to inter-site discussion and interaction. This was largely because inherent VoIP audio delays. The host site at CU could not maintain a continuous audio stream with participants without an echo of the lecturer being heard. This meant that someone had to monitor incoming audio requests and unmute the sound to engage them. It is very difficult for the lecturers themselves to perform this task while lecturing. Future technology must be able to facilitate both the lecture and discussion environments.

In order to encourage interaction and even collaborative work on course projects, it is helpful for the students form a community by getting to know each other. Professional relationships so established will likely be an important basis for interdisciplinary collaboration well into their careers. One way to facilitate this important development of community is to have the students participate in summer schools or programs outside of their home institution. We have made preliminary progress in this regard. Several CGEP students have participated in the Heliophysics Summer School run with NASA support at HAO/NCAR. We have also had four graduate students attend the Professional Development Program (PDP) jointly sponsored by the Akamai Workforce Initiative (AWI/UH) and the Institute for Scientist and Engineer Educators (ISEE/UCSC, University of California, Santa Cruz). Through this program they developed inquiry-based activities that were then used in the CU/LASP summer REU program, providing the undergraduate students in the first week of the REU program an experience that mimicked and prepared them for authentic scientific research while simultaneously teaching basic concepts of solar physics. To prepare these activities, the graduate students in the PDP took part in a week long "Inquiry Institute" during which they were taught the fundamentals of engaged learning, a two day "Design Institute" where the bulk of the activity was developed, and a brief "Facilitation Workshop" shortly before the activity to ensure preparedness. Two of the four graduate students have attended the PDP program a second time, advancing to design-team leadership positions. The remaining two students will likewise follow up with second year attendance in the coming year, resources permitting.

Future efforts:

The inaugural Spring 2013 class experience has renewed our enthusiasm for addressing some of the graduate educational needs of the solar and space physics community using a tele-education environment. The next steps include:

- Spring 2014 offering of the next course through the CGEP program, titled "Magnetospheric and Ionospheric Response to Solar Output," with the host site at NJIT.

- Joint formulation of a graduate course curriculum by CU, NJIT, UH, NMSU, MSU, HAO, and NSO, including definition of the course or course module offerings and institutional or individual responsibilities for teaching these. A preliminary list of course modules that instructors at the different organizations may take individual ownership of, and that together might form the basis of a curriculum, with two or three modules making up the course each semester, might read:

  Helio and asteroseismology
  Global scale solar dynamics and dynamo processes
  Radiative magnetohydrodynamic turbulence in the solar photosphere
  Non-LTE radiative transport and spectropolarimetric techniques
  Solar instrumentation
  Instrumentation for In situ measurements of particles and fields
  Adaptive optics in astrophysics
  Observational properties of the solar cycle
  Solar radiative output and variability
  Solar chromospheric dynamics
  Solar coronal structure and stability
  Flare physics -- acceleration and heating
  Solar wind structure and dynamics
  Shock formation and particle acceleration in the solar wind
  Solar wind interactions with planetary magnetospheres
  Large-scale structure of the solar heliosphere and extrasolar asterospheres
  Cosmic ray origin and transport

  Each of these, if adopted, must be supported by a well-developed curriculum that ensures highest quality graduate education employing source material, problem sets, and inquiry based activities.

- Development of community building programs at the host institutions. We would proposed the following:
  - UH/UCSC continue their involvement of CGEP students in its Akamai PDP efforts
  - CU/HAO develop a two week summer program in computational methods in solar and space physics
  - NJIT/NSO develop a two week summer program at Big Bear Solar Observatory focused on solar observational astronomy
  - Future participants focus on a complementary program in solar and space physics data analysis and interpretation

- Reflecting our broader commitments, extending these efforts to include undergraduate course offerings, and make these courses and opportunities available to, and enable participation by, Minority Serving Institutions (MSIs).

- Acquisition of more effective technology in support of tele-education, to provide an environment that is truly interactive between sites and thus facilitates learning at the highest level.

Estimated costs of the last bullet item above:

Cisco's TelePresence (TP) offers a very effective interactive environment for carrying out a distributed classroom involving multiple sites. It enables high-definition (HD) video streams separately for (a) content (such as PowerPoint, Keynote, or a digital whiteboard) and (b) presenters and audience, with the latter being captured by multiple steerable cameras at each site. The incoming video streams from other sites can be displayed variously on large HD flat displays or projected onto large screens, allowing flexibility as to how any given room is configured. The sound streams can be handled using ground lines, thus overcoming VoIP audio delays.

Implementing TP for the CGEP requires investment in "core video infrastructure" (CVI) at one site that can be shared by all participants, and this in Cisco's language involves a MCU (video bridge-multipoint conferencing unit), a TMS (management and scheduling server), a VCS (centralized video call control server), and a VCS Expressway (centralized firewall traversal). CVI equipment that can handle five sites costs $109.9K, which includes a three-year service cost of $20.3K, all quoted with educational discounts (see attached budget detail). In addition, each classroom site ("endpoint") requires a room-based component system (Codec) that is an integrated package controlling all video streams, two cameras and audio. A number of options for the Codec endpoints are available, but the C60 Codec endpoint appears to balance cost and flexibility. It costs $38.5K, which includes three year service cost of $7.5K, with details in the attached budget document. In addition to the C60, each classroom would require two HD video projectors or displays (~$7K) and a sound system (~$3K), assuming that other classroom costs are met separately. Thus each classroom site has an overall cost of $48.5K.

In summary, a TP interactive environment involving five classroom sites costs about $352.4K. Adding additional TP sites would cost $48.5K plus a MCU license of $7.2K. Similarly, if the TP environment had four classroom sites its implementation cost is reduced to $296.7K, and for three sites to $241.0K. Detailed cost estimates from Cisco are attached for both the TelePresence core video infrastructure (CVI) and for each endpoint Codex C60, with three-year service costs included.

Such TP environments allow other participants to join via WebEx, at costs comparable those outlined in the Spring 2013 classroom description above. This allows greater flexibility for broader participation beyond the core TP sites, and may facilitate incremental expansion. The classroom presentations would also be recorded via the WebEx compatibility, providing an excellent way to review the material at any later time or nonsynchronous accessibility to others beyond the CGEP.