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Distributed Departments: A New Approach to Protecting the Vitality of Small Programs

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Abstract The Texas Electronic Coalition for Physics was established in 2000 as a means of demonstrating that by linking together, small programs can maintain their vitality in higher education. Using Interactive Television, the Internet, telephones, faxes, and other electronic media, five physics programs scattered across the state of Texas formed a distributed physics department. In addition to jointly offering lecture courses, the group (i) established procedures for operating as a unified entity, (ii) encouraged research regardless of location, (iii) provided a locus for professional camaraderie, (iv) created a distance-based advanced physics laboratory course, and (v) developed assessment tools for measuring success in a distance environment. Through these, the coalition demonstrated that a distributed department can carry out all of the functions associated with a traditional department.

Keywords Distributed departments · Distance education · Interactive television · Technology assisted teaching

Introduction

The new century has been a difficult one for higher education in the United States. Since 2000, almost 80% of the states have had a budget crisis that has severely impacted funding at their public institutions (Arnone 2004; Hebel and Seling 2001; Potter 2003; Schmidt 2000; Schmidt 2002). Private schools have fared only marginally better; they have suffered financially due to drops in the stock market, thus affecting endowments, and in philanthropy. While these crises affect institutions as a whole, their effect

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is worse on small departments. Budgetary and personnel limitations act as a strong constraint on the range of options available to these departments. Minimum enrollment and graduation rate requirements amplify the problem. While there are similar problems in private institutions, the authors' experiences are in public universities, so this paper will focus primarily on those.

At many public institutions, courses must have a minimum number of students enrolled for a course to receive state support. If the course does not reach this minimum number, then it is either canceled or it is not counted as part of the faculty member's teaching load. For small programs, this is often a problem with upper-division classes intended only for majors. If these courses don't "make", then the program and its faculty face two choices. Either they can teach these courses as overloads that do not count as part of their work load, or else they cannot offer them at all. Neither option is good, as either the faculty are subsidizing the program by teaching for free, or else they risk losing the program completely as the students go elsewhere for required courses.

Additionally, in many states there are governmental boards that oversee public higher education. These boards establish rules that determine if a program is productive or not. Usually this is based on the program's graduation rate. If the rate is not high enough then the board may recommend that the program be discontinued. Even if the program is not targeted directly, it can be threatened indirectly. Particularly in tight budget years, if an institution wants to establish a new program it is told that it must give up another program. Under these conditions the institution may choose to cancel the small program voluntarily.

These two threats, the inability to teach required classes to majors as part of the regular teaching load, and the need to maintain a high graduation rate, put a severe strain on a small program. For concreteness, we define a small program to be one that satisfies several of these criteria:

- contains four or fewer faculty members;
- has 30 or fewer majors;
- graduates an average of 2 majors per year, or less;
- due to a lack of sufficient enrollment has difficulty offering upper division courses for majors;
- is embedded within a larger, multi-disciplinary department, with the associated risk of being marginalized; or
- does not have an associated graduate program.

The authors recognize that this definition is not an inclusive one, and many small programs do not satisfy all of these conditions. However, many of the issues we discuss exist for programs satisfying only one of these conditions, so the above list provides a good operational definition. It applies to many programs in physics, philosophy, English literature, mathematics, geology, classical studies, and foreign languages, among others.

Faced with these problems, small programs frequently find themselves forced into a reactionary mode. The program usually has scant resources, both financially and in terms of personnel, and what little it has is forced to focus almost exclusively on issues surrounding survivability and the immediate threats to the program. Because of this, very little energy is left for the long-term strategic planning necessary to transition the program into a stronger, more viable position within its institution.

An example of the problems facing small programs can be seen by looking at physics programs. Smaller, predominantly undergraduate institutions across the country are finding it increasingly difficult to maintain enrollment in physics courses beyond those classes that are service courses for other departments and majors. This has been identified as a national problem, and was the major topic of discussion at the 1997 Physics Departmental Chairs Conference (Kirby and Gollub 1997). Throughout the United States, physics departments at undergraduate institutions have few majors and frequently graduate only one or two students per year. According to data gathered by the American Institute of Physics, over half of the U.S. institutions granting physics degrees award fewer than five baccalaureate degrees per year. The number of institutions in this category grew during the late 1990 s, increasing from 55% of the colleges and universities that responded to their survey in 1994 (Mulvey et al. 1995) to 62% in 1999 (Nicholson and Mulvey 2000). Even though this trend reversed in the early 2000 s, the number of institutions awarding fewer than five baccalaureate degrees per year remained above 50% through 2006 (Nicholson and Mulvey 2007).

This trend can be seen more dramatically by looking at the number of institutions granting baccalaureate degrees over time. Figure 1 shows the distribution of the number of schools awarding degrees as a function of number of physics degrees awarded from 2000 through 2006. This includes all institutions responding to the annual American

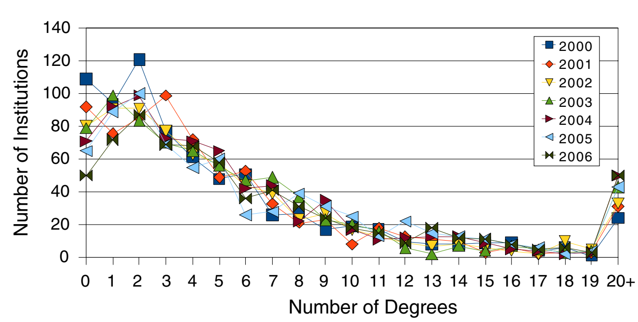

Fig. 1 Number of physics degrees granted by all reporting institutions

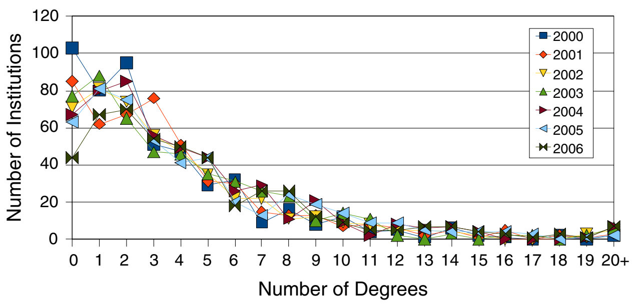

Fig. 2 Number of physics degrees granted by baccalaureate only institutions

Institute of Physics survey. The improved graduation rate is dominated by improvements within schools offering graduate (master's and doctoral) degrees. When these institutions are removed from the sample, the number of institutions awarding fewer than five baccalaureate degrees per year remains above 60% for the period 2000–2006. This is shown in Fig. 2.

In response to these challenges, a physics consortium was established among five Texas A&M University System schools. This consortium uses modern communications technology to link five programs that are spread across Texas into a single distributed department. As a result, the viability of the physics programs at all of the participating institutions has been significantly improved. An additional benefit has been the consortium's ability to capitalize on the increased availability of diverse expertise across the member institutions.

The use of video and the Internet to teach classes is not new. The Open University in England was one of the first schools in the world to enter this area, and is still one of the main producers of audio- and video-based course content ("Open University" nd). In the United States, the Western Governors University (Western Governor's University 1998), University of Phoenix (2006) and the University of Maryland—University College (2008) provide major portions of their school's content via distance education content. Closed-circuit and standard broadcast television, along with video and audio tapes, are staples of many distance education departments. Similarly, there are many projects in physics aimed at creating a more active learning environment (Activity Based Physics 2003; Wilson et al. 1992a, b), primarily though the use of technology, as well as classes offered electronically via the World Wide Web (Smith and Taylor 1995). However, very few projects have attempted to offer courses that are both received at and originate from a distributed network of campuses, nor have they attempted to combine separate departments into a unified entity. Among those programs that have attempted this in physics are those at the South Dakota State University, Itasca Community College, and Hibbing Community College in Minnesota. South Dakota State University used Interactive Television (ITV) to teach upper division courses, while Itasca Community College and Hibbing Community College linked their programs to also create a "virtual" department using ITV. The University of Colorado has created a virtual geography department (Virtual Geography Department 2004), but this project focuses on developing geography teaching materials to be shared across the nation, not on forming a formal department that is distributed. Similarly, the International Virtual Institute for Historical Studies of Mathematics (Barreau 2002) created an organization for scholars studying the history of mathematics, but without the administrative aspects of departmental structure.

History

In the early 1990 s, three Bachelor's degree granting physics programs in the Texas A&M University System were facing the problems described above. At West Texas A&M University (WTAMU) and at Tarleton State University (TSU), faculty were not allowed to teach classes that did not have the requisite enrollment of ten students. This meant that they could no longer teach several of the classes required by their majors. At Texas A&M University-Kingsville (TAMUK), the faculty were able to teach these classes, but only if they were not considered part of their normal teaching load. However, at TAMUK there was pressure to eliminate low-productive programs. The overall result was that all three schools were in danger of losing their physics program.

At the same time, the Texas A&M University System (TAMUS) was investing heavily in establishing a system-wide broadband videoconferencing system, the Trans-Texas Video Network (TTVN) ("Information about TTVN" nd). Originally intended to enable administrators at the various institutions within the A&M System to interact without having the expense and down-time associated with travel, it was quickly seen that this use alone was insufficient to justify the expense associated with the network. Jimmy McCoy, then chair of the Department of Mathematics, Physics, and Engineering at TSU, which included the physics program, suggested that the TTVN system be used to teach physics classes. This would not only increase usage of the network, but could also address the problems threatening physics programs throughout the state. He contacted other chairs of departments with physics programs, and Lionel Hewett, then chair of the Department of Physics at TAMUK, and Vaughn Nelson, the WTAMU chair of the Math, Physical Sciences, and Engineering Department at that time, both agreed to join in this effort.

Before the first course could be broadcast, organizational and technical details had to be worked out. The three chairs decided on a core set of eight courses that would be taught over a two year period. All three institutions had to adjust the course numbering and description in their catalogs to ensure uniformity. Days and times had to be coordinated through the central TTVN hub to ensure network availability. The most important task was getting the Texas Higher Education Coordinating Board (THECB) to agree to count the total enrollment at all three schools as the official enrollment at the broadcasting institution. These tasks were all accomplished and the first class was offered in the Fall of 1992.

Originally taught solely over the TTVN, the nascent coalition cycled through its courses, learning the tricks and techniques necessary to teach in this new medium. Midwestern State University (MSU) began receiving classes from the group in 1994. However, relying completely on the TTVN led to a number of significant problems. Technical problems associated with the videoconferencing network resulted in the loss of class time, as different campuses occasionally failed to connect. Academic calendars on the different campuses were not synchronized, so more time was lost waiting for the last campus to start their semester and finishing when the first campus started their final exams. During the Spring semesters, differing Spring breaks led to additional lost time. The end result was a reduction in the content covered in these shared courses in comparison with their traditional counterpart. These problems resulted in MSU withdrawing from the coalition in 1996.

Despite these problems, the coalition added two members in 1995. While neither Texas A&M University-Corpus Christi (TAMUCC) nor Texas A&M International University (TAMIU) offered degrees in physics, both institutions offered a minor in physics, and so faced many problems similar to those of the original three programs. By joining the coalition, both schools began to be able to offer upper-division physics courses to their students on a routine basis.

At the same time, the explosive growth of the Internet provided another avenue for teaching over a distance. The advantage of hybridization of the Internet and TTVN was quickly recognized, and in 1997 the Optics course was modified to take advantage of this new mixed medium (Suson 1996, 1997). Almost immediately, the topic coverage jumped back up to near the level covered in a traditional course as the asynchronous, 24/7 nature of the Internet neutralized many of the time constraints inherent in relying solely on the TTVN.

By 1999, the original threats to the programs had receded and faculty settled back into routine. While the advantages of the hybrid approach were recognized by many of the faculty, the large investment in time, both in developing the materials and learning how to post these on the Internet in a readable form, was too much without appropriate institutional support. Changes in personnel and new local programmatic directions drew the focus away from the coalition.

As a result of these problems, the group began discussing ways to reinvigorate the coalition. It was decided to look at expanding beyond a loose coalition of programs that shared courses into developing an electronically connected, geographically distributed department (Suson et al. 1999). This concept was funded by a grant from the U.S. Department of Education's Fund for the Improvement of Post-Secondary Education (FIPSE) program, and the Texas Electronic Coalition for Physics (TECP) (Texas Electronic Coalition 2005) was born.

Components of a Distributed Department

As a distributed department, the TECP had to develop a number of components. Among the associated tasks were

- Optimization of the eight original courses for teaching via the hybrid method;
- Development of two additional courses;
- Demonstration of the feasibility of conducting research involving students and faculty in the TECP regardless of location;
- Establishment of rules governing the operation and growth of the TECP;
- Establishment of protocols and agreements detailing the rights and responsibilities of the TECP with respect to the participating institutions, as well as with respect to the State of Texas;
- Creation of mechanisms establishing esprit de corps among the faculty and students in the TECP; and
- Establishment of a centralized server to act as a departmental office.

In tackling these challenges, the faculty had to always address an additional, unwritten requirement, namely, was the solution to this particular problem generic enough for adoption by other institutions? As a result, the coalition often faced the following dilemma. One solution took advantage of the unique nature of the TECP and its relationship with its participating institutions. As a result, this solution was usually fairly straightforward to implement. Another solution, often more involved, would be more generic in nature. The requirement of acting as a national model often tilted the decision in favor of the generic solution, even though it was more difficult to implement. This ensured that the solutions found by the TECP could be translated to other programs adopting a similar model.

Developing a distributed department is a multi-faceted process, involving course development, administrative challenges, and communications issues. It takes perseverance and dedication to make it work, but the results are well worth it.

Developing Courses for Use by a Distributed Department

The heart of any educational endeavor lies in the courses that it provides. These form the backbone upon which a strong educational experience is based, producing well-educated graduates. In order to be viable, a program must provide a sufficient range of courses to ensure that students: (1) gain the skills necessary to prepare them either to enter their profession or to pursue additional professional education, (2) remain enthusiastic about the subject so that a love of learning and of the profession is instilled in them, and (3) have an opportunity to learn about, and sometimes participate in, cutting-edge advances. For a small program, this can be difficult under the best of conditions. Limitations associated with the number of available faculty, as well as the small number of students in the major, usually force small programs into a multi-year course cycle. In addition, these constraints also make it difficult to offer many courses beyond those that form the professional core. Hence, the challenge to meet the second and third requirements for a viable program can become insurmountable.

Via a distributed department, small programs can address this challenge. The additional faculty available at partner institutions allow the core classes to be spread among all of the participating programs. This ensures that the required courses are always available and that faculty are able to mentor students appropriately. It also frees local resources for teaching additional elective courses, conducting scholarly activities, and including students in scholarly activities. The combined student enrollment helps ensure that courses have the minimum headcount required by administrators. By enabling programs to look beyond immediate survival needs, they can begin carrying out those additional steps necessary to meet the objectives outlined above.

There is a practical downside to teaching in a distributed manner, however. As faculty in the TECP learned, offering classes at a distance is not as simple as walking in front of a camera and offering a traditional lecture. With interactive television, the immediacy of student feedback is lacking. Many of the nonverbal cues that instructors rely upon are no longer available. Things that were never considered before, such as nervous gestures, walking around while talking, and even what to wear become important. It is critical that the instructor understand the capabilities, and limitations, of the system before starting the course. Among the questions that should be answered are:

- Is the television system capable of displaying only the students at one campus at a time or can it show students at multiple campuses simultaneously?
- What is the maximum number of campuses that can be simultaneously displayed?
- How large are the images on the broadcasting and receiving campuses?
- What level of technical support is available at each campus?
- Are there fax machines, or other communications equipment, readily available in each studio?
- What are the capabilities of the document camera system?
- What type of multimedia and Internet capabilities are available in the studio?

The answers to these questions are important for one simple reason: to a student on a remote campus, the instructor is often reduced to being a “talking head”. Faculty must modify their teaching style to minimize this effect. The experience of the TECP faculty has shown that this is best accomplished by maximizing the interactions of the students, particularly those on the remote campuses, with both the instructor and the other students. Many of the techniques associated with active learning are not only applicable in this medium, but help optimize the learning experience.

One interesting result was that TECP faculty found that the use of the Internet along with interactive television acts as a force multiplier in terms of the level of learning seen in the students. The use of the Internet as an instructional medium is not new. Indeed, most institutions of higher education now offer Internet-based courses. Similarly, blended courses that combine interactive TV with face-to-face teaching have been offered and studied for quite a while (Rovai and Jordan 2004). However, the authors are aware of only a few projects that combined interactive television with the Internet (Gurocak 2000; Woo and Ng 2003). Subjective feedback from students indicates that this hybrid method of teaching is, at least for technical subjects, superior to both purely interactive television and pure Internet usage. This is primarily due to the extended time that the material is available for study on the Internet, which effectively eliminates many of the technical problems associated with a pure interactive television environment. On the other side, purely relying upon the Internet does not always address the various learning styles found in students. In particular, the use of interactive television allows the student to clarify and seek answers to questions on material that they did not understand. For subjects such as upper-division physics, which relies heavily upon understanding not only the steps but the implications of a derivation, this interactive ability can represent the difference between grasping and not grasping a difficult concept. The interactive television sessions also act as a pacing mechanism, creating an external mechanism that forces the students to remain current in the course.

Since Internet-based materials play such an important role in teaching classes within a distributed department, special attention must be paid in creating these materials. While individual styles may vary, students and faculty involved in TECP courses have all recognized that the more detailed the Internet material, the better. From an instructor's point of view, this creates a significant challenge. As one TECP faculty member has observed, the process becomes very similar to writing a textbook.

Just as it takes considerable time to write a quality textbook, so too does it take time to develop quality course materials. While some institutions have policies providing release time for creating Internet materials, many others do not. Course management systems, such as WebCT and Blackboard, can make development and presentation of these materials easier, but also can have large learning curves. Creating multimedia, interactive components, pictures, and equations can be a challenge above and beyond that associated with simply generating the text. In many cases, these additional items are more of a hindrance than a help to the faculty member. Again, while some schools provide staff that can help create these items, many others do not. In the latter case, either the local or distributed department may find that they have to provide funds to hire qualified students to assist with material development.

Efforts to develop physics curricular materials for use on the Internet have taught TECP faculty that it is important that these items be as "reader-friendly" as possible. This is especially true of the primary course notes. Equations should be presented as gif or other image files, or else in MathML. The weakness of the former approach is the potential for creating web pages that are particularly slow to load, as each equation resides in a separate file that has to be downloaded from the server. The problem with the latter is that support for MathML is not widespread, so an equation that is readable on one type of computer using a particular browser might not come through on another computer or another browser. While the authors are confident that there are numerous methods to work around this (such as cascading style sheets), it should also be mentioned that investigating and mastering such solutions often represents such a large investment in time and effort as to act as another detractor from the main focus of producing high-quality content.

Particular attention has to be paid to tests and homework. In this area the TECP was fortunate to be able to draw upon its previous experiences. Homework was usually scanned and emailed, or else faxed to the instructor of record. Originals were sent via regular mail as well. Student results were usually emailed, with the graded papers returned via regular mail. Tests were administered locally. The instructor would email or fax the test to the local coordinator, who would then proctor the test locally. Faculty also made greater use of take home exams, particularly in order to accommodate differing final exam schedules.

In the absence of a large block of release time, the time commitment associated with creating a strong Internet course component can only be addressed by envisioning development as a multi-staged process. Each time the course is to be offered, additional layers are added, improving the quality of the overall site. This approach automatically broaches the question of depth versus breadth. Is it better to focus on developing a site that covers all of the desired material in some manner with subsequent revisions deepening the coverage, or should the key areas be developed completely from the start, with additional topics added later? While the answer to the question depends both on the type of course and the instructor, tackling this question led the TECP to the realization that it was first necessary, as a department, to identify and agree upon a list of topics that would be covered in each course regardless. Only in this way could the TECP ensure that course coverage would be consistent no matter where the course content was developed or hosted.

After topic lists were created, the question of depth versus breadth was again approached. As expected, the answer depended on the type of course. Those courses that were survey courses, such as Modern Physics I and II, Mathematical Methods of Physics, and Computational Physics, needed to focus on breadth first. Courses that were concerned with a single topic, such as Classical Mechanics, had the option of focusing either on breadth or depth, depending upon the preference of the course developer.

In the end, the courses being offered by a distributed department form the core upon which it will succeed or fail. In turn, the efforts put into development, presentation, and management of these courses directly impact the quality of the material and, in turn, dictate the level at which students grasp the concepts being presented.

Governing a Distributed Department

Teaching courses via distance educational techniques is neither new nor particularly innovative. Indeed, the programs participating in the TECP had been sharing courses for many years prior to the formation of the Texas Electronic Coalition for Physics. The transition between the earlier informal group and the distributed department was marked by the expansion of the goals associated with the group. In order to ensure that these goals were both shared and understood by all of the institutions participating in the coalition, a series of formalized agreements were created.

Because the TECP intended to do more than simply offer courses to its members, establishing guidelines for its governance was essential. This gained additional importance with the understanding that the role of physics, as a program, as a department, and as an area of education, varied greatly from institution to institution. Providing a common set of rules outlining the goals of the TECP, as well as a common set of operational rules, formed the foundation upon which the coalition was established. The rules are provided by the Bylaws of the TECP, which can be seen at the TECP website (Texas Electronic Coalition for Physics 2005), or upon request from the authors.

As with many of the issues tackled by the TECP, the Bylaws were created with an eye towards a national model. Items such as dealing with funds associated with the coalition directly were included even though they are not anticipated to have to be dealt with by the TECP itself. This has continued to drive the development of the governing rules even though the original FIPSE grant has ended.

One major provision of the Bylaws calls for the establishment of an advisory board. This board provides a mechanism for establishing goals internally as well as enables valuable feedback from external constituents. This is accomplished through the makeup of the board. As specified in the Bylaws, each of the participating programs has a member on the advisory board, providing one vote to each of the full members. However, in addition to this representative, the head of the department containing the physics program, and the appropriate college's Dean, have been invited to participate in board deliberations. While they do not have a vote, the input of these additional members has been invaluable to the group and has helped the TECP navigate the sometimes turbulent waters of academia.

In addition to developing rules to govern itself, formalizing the relationships between the TECP and the institutions participating in it were also important. In order for the coalition to work, the rights and responsibilities both delegated and denied to the TECP had to be explicitly stated. This was accomplished through the use of Memoranda of Agreement (MOAs).

Generic MOAs are available at the TECP web site or upon request from the authors. There were two types of MOAs created. The first is the MOA for institutions joining as full members. Full members both broadcast and receive courses, take part in collaborative research projects, and have representation on the TECP advisory board. The second is the MOA for associate members. Associate members only receive courses and do not have a vote on the advisory board. Both MOAs consist of three main sections: the primary section that outlines the rights and responsibilities of each institution and the TECP, a section that tabulates course equivalencies between local course nomenclature and a common nomenclature within the TECP, and a final section that enumerates details of course offerings and tuition exchange. This last section is of particular interest as it provides a major incentive for smaller programs.

By using these documents the TECP operates within a well-defined organizational environment. Participating institutions are guaranteed that the TECP will not attempt to usurp the roles of the local departments, while they pledge to support the efforts of the group even when they don't have local students enrolled. This latter aspect has been extremely useful in ensuring that courses originating from one campus continued to be offered on a regular basis regardless of local enrollment. In turn, this has ensured that the TECP has been able to carry out the basic duty of a distributed department; namely that of maintaining a rotation of courses that enables students to plan their schedule effectively and graduate in a timely manner.

Tuition exchange can be both the most important part of the MOA, as well as the most difficult to implement. Institutions participating in the coalition have to agree on a uniform amount of money associated with each coalition related credit hour generated by every student enrolled in a coalition class. A mechanism, including procedures and deadlines, for transferring the funds has to be developed.

For the Texas Electronic Coalition for Physics, this was accomplished by taking advantage of the facts that all of the institutions were not only public institutions of higher education, but also contained within the same higher education system. The Registrars' offices at each of the participating institutions exchanged the pertinent information on students enrolled in the TECP courses, with the information being sent from the receiving institutions to the broadcasting institution. The students were then entered (and appropriately flagged) into the local registration system so they could be reported to the State as if they were enrolled at the broadcasting institution. Simultaneously, the receiving institutions reported zero enrollment for the coalition class being received. Based on these reports, the state-mandated portion of the tuition, which is uniform among all of the participating institutions, was sent to the broadcasting institution instead of the receiving one. It is important to note that while the students were reported as being at the broadcasting institution in terms of tuition exchange, they always remained enrolled at their local institution in terms of registration and degree receipt. The exchange of registration information in this case is simply an expedient to ensure tuition exchange takes place automatically.

When some of the institutions involved are unable to use an equivalent exchange mechanism, more direct solutions are required. The greatest impediment is usually associated with the low number of students involved at any one campus. The argument is usually based on the assumption that the overhead involved in implementing the exchange is more than will be transferred. This is where a counter-argument showing the differential gain can be used.

One of the greatest advantages of tuition exchange is that institutions with only a few students in the coalition gain in proportion to those institutions with a greater number of participating students. The loss of income associated with one or two students taking a course remotely per semester is easily outweighed by the gain realized whenever that institution is broadcasting a course. In the long run, since the distribution of broadcasting is spread across the institutions, the programs with the lowest numbers of students derive the greatest income from the coalition. In turn, this helps maintain the vitality of the program at that institution.

Addressing Enrollment Issues

As was already discussed, one of the driving reasons for combining together to teach classes remotely was low numbers; the low number of majors in the various courses and the low number of students within the individual programs. The issues associated with low numbers in courses were addressed through the development of agreements between the participating institutions. Solving the problem of low programmatic enrollment was one of the primary motivators behind the formation of the TECP. This is a problem for small programs in general. Without external stimulus, which is often unplanned, all of the energy within the program is required to simply maintain enrollment at a constant level. Since external stimulus can take any number of forms, ranging from the loss of a faculty member, the enrollment or graduation of a charismatic student leader, or the receipt of a gift from a former student, the effect on the program can be significant. Unfortunately, while the external stimulus can lead to an increase in numbers, more often than not, for a small program the change is for the worse. This follows from the realization that positive changes within small programs are often absorbed within the larger structure, while there is no margin for absorbing similar negative changes. Either way, the new number forms a new plateau which the program then struggles to maintain until the next change buffets it.

By teaming together as a distributed department, individual programs can pool resources and so begin to focus on becoming proactive instead of reactive. In the case of the TECP, grouping together enabled the participating institutions to at least maintain their enrollment levels or, in most cases, begin to build their programs. This can be seen in Fig. 3. The growth at Tarleton reflects their addition of an engineering physics major, while the numbers at the other institutions are stable during times of significant refocusing of the individual programs. It is particularly useful to note both TAMUCC and TAMIU only offer a minor in physics. Their participation in the TECP enabled students to remain in the program and receive enough courses to earn the minor upon graduation.

Figure 3 also demonstrates an important strength of a combined department. With the exception of TSU, none of the other programs within the TECP were strong enough individually during this time period to avoid being classified as a low-productive program. However, since the Texas Higher Education Coordinating Board viewed the institutions within the TECP as a combined program, only the total number was considered. As a result, none of the programs were stigmatized with this label and all were able to focus on methods of building their individual programs.

As mentioned at the beginning of this article, the two critical areas upon which the programs that formed the TECP are judged are number of graduates and individual course enrollment. The ability of the TECP to address the number of graduates is addressed above. The TECP also had a positive impact on the individual course enrollments. Figure 4 shows the enrollments in courses offered by the TECP during the 2002–2005 academic years. Note that, with a few exceptions, the total enrollment in all of the offerings is above the minimum requirement of ten students. Among the courses that are below this number, the Advanced Lab and Computational Physics courses were brand new, while the two graduate courses were offered by TAMUK as a means of building interest in a graduate program. Given the fact that none of the participating

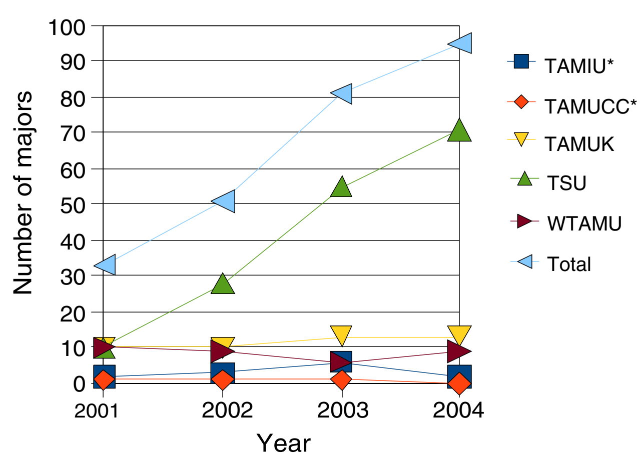

Fig. 3 Number of majors at each institution, as well as total, during the funded years of the TECP. Note that TAMIU and TAMUCC, both denoted by *, only provide a minor in physics

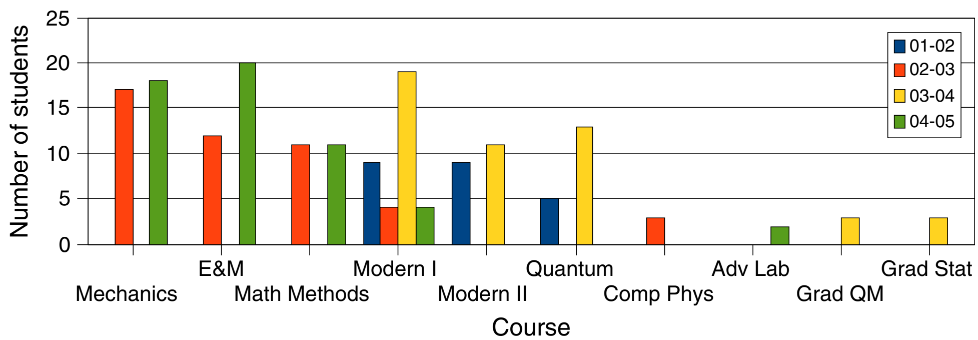

Fig. 4 Enrollment in the various TECP courses offered during the grant period running from Fall 2001 through Spring 2005

schools had a graduate major, the fact that students enrolled at all is a testament to the TECP's ability to service students that could not be reached normally.

Two core classes, Modern Physics I and Quantum Mechanics, require additional elaboration. Modern Physics I is recognized as a gateway course in that it acts as the prerequisite for both Modern Physics II and Quantum Mechanics. In order to enable more students to make improved progress towards their degree, the TECP experimented with offering Modern Physics I on an annual basis, instead of the traditional two year cycle. As can be seen from Fig. 4, not only did this experiment not increase student graduation rates, but it resulted in a reduced enrollment in the course during the period of the grant.

The 2002 offering of Quantum Mechanics is also below the traditional cutoff of ten students. In this particular case, a number of students decided to take Modern Physics II, which is an elective course, postponing when they would take Quantum Mechanics.

Maintaining Communication Among Participants

In order for a department to provide an optimum learning environment, it is essential that the departmental members interact with each other in a positive way. This does not necessarily mean that all of the faculty agree on all matters, but rather that all of them conduct themselves professionally with the best interests of the department in mind. An essential element of this esprit de corps is making sure that all of the members are aware of departmental plans and policies, as well as the department's role in the institution's mission.

A distributed department is no different. Indeed, the problem is magnified by the distance separating the members. Simple discussions of everyday events, shared lunchtime debates, conversations about friends and family, all the things that establish community in a local department become nearly impossible in a distributed department. Technology must be used to replace locality.

The Texas Electronic Coalition for Physics uses a number of mechanisms to enable communications. Telephone is the easiest means of talking between members. Talking to a colleague on another campus becomes no different from talking with one on another floor. However, the same advantage that telephones offer is also their weakness. Most people are trained to keep business conversations short and to the point, ensuring that both parties are able to concentrate on the discussion and then get back to work. Personal calls are discouraged and are usually kept to a minimum, both in number and duration.

The limitations associated with the phone are often circumvented through the use of email. Not only does email provide a means of carrying out a more in-depth discussion, but also archives the flow through saved messages. Email also allows more than two people to participate in the discussion. The TECP uses a number of distribution lists to host various discussions. All of the faculty in the TECP are part of the main mailing list. This is the primary means of carrying out discussions relevant to the whole collaboration. Additional lists are maintained for the advisory board and the astronomy research group. More lists will be added as the need arises. All of the distribution lists are maintained by the administrative computing staff at TAMUCC, ensuring backup and archival services automatically.

While email and phone calls help tie the coalition together, they are not good replacements for direct communications, nor do they take full advantage of technology. Since the TECP already taught its classes via interactive television, it was natural to use this for meetings as well. From the beginning, the group began holding monthly departmental meetings via TTVN. These meetings would focus on questions typically dealt with by a department, such as course objectives and content, improving student recruitment and retention, and collaborative research opportunities.

As Internet bandwidth has improved, the group has begun investigating other means of communications. Portable video cameras using the same compression algorithms that are used by the interactive television system have been purchased for use in the laboratory course. In order to address the problem of remote office hours, webcams have been purchased for all of the TECP faculty, as well as a camera for student use. These will enable the instructor to maintain traditional office hours while keeping their camera on. If a student on a remote campus wishes to talk with the instructor, they go to the computer with the web camera and connect to the professor.

Electronic communications have improved interactions throughout the TECP to a level roughly equivalent to that found in a normal department. However, these modes do not fully transmit non-verbal cues, and are frequently constrained by time. These issues were recognized from the start and addressed by including a face-to-face meeting each semester. These meetings were rotated through the participating institutions, enabling the TECP faculty and advisory board members to tour the facilities at each campus. A full day was allocated for these meetings, which included both a departmental meeting of all of the faculty and a meeting of the advisory board. These meetings were typically spread over two days, with the advisory board meeting on a Friday afternoon and the faculty meeting on Saturday morning. The whole group would go out to dinner on Friday evening, enabling people to learn more about each other in an informal environment. The importance of the face-to-face meetings was immediately recognized as playing a key role in providing a mechanism for dealing with involved topics in a single meeting and also building a sense of unity among TECP members.

The Distributed Office

The last major aspect of a local department that must be replicated by a distributed department is the central office. The main office serves as a central repository for a department. Records on current and past students are stored there. Information on classes, books, and faculty assignments comes from this office. All of these capabilities need to be duplicated for the distributed department.

The very nature of a distributed department makes a physically centralized office impossible. Even if the office was located on the same campus as the coalition's chair, moving the records as the chair changed between campuses would quickly become impractical. Fortunately, technology again provides the best solution to these problems.

The last ten years has seen a continual shift from paper records to electronic. Not only has this eased the paper storage problem for a local department, it has vastly simplified the concept of a distributed office. A dedicated computer now has the same functionality regardless of whether the department is located within the same building or spread across the state.

The TECP's computer is located at Texas A&M University-Corpus Christi. In addition to holding the coalition's web site, the computer maintains a database that tracks students, courses, and faculty assignments. This database enables faculty to easily see a complete list of students registered in their classes. It also provides a mechanism for tracking TECP students by showing not only those TECP classes that the student has taken, but also when, under what instructor, and what the final grade assigned was. This allows faculty to track student progress and advise the students appropriately.

Additional functionality is planned for the departmental computer. As part of its commitment to the TECP, WT-Online staff created a series of computer- and TTVN-based training modules for teaching in a distributed environment. These modules will be installed on the computer for use by TECP faculty. The computer will also be used as a server as the group obtains software that can be shared. Faculty will be encouraged to use the accounts already established on the computer for shared projects. Finally, computer-based assessment tools, originally developed at Texas A&M University, have been installed on the departmental computer.

Conducting Research at a Distance

In addition to offering courses, a vibrant department provides opportunities for its students to participate in the creative endeavors of the profession. For the TECP, this meant establishing a mechanism for students to take part in research projects with faculty, regardless of where the students and faculty are located.

Traditionally, students find projects by talking with the faculty, visiting their labs, and observing the work going on. While this can be emulated on a limited basis in a distributed department, for the most part another approach must be substituted. In the TECP this took the form of determining the research interests of each faculty member and publishing this information on the distributed department's web site for students to see. Information on projects that can involve students is also collected and distributed electronically. Faculty at each campus are encouraged to make sure that their students are aware of these opportunities, as well as to consider using students from other TECP institutions in their research projects.

Physics research projects generally fall into one of three categories: experimental, computational, or theoretical. Theoretical projects are the easiest to implement over a distance, but the most difficult to carry out with undergraduate students. Students are not usually sufficiently prepared to engage in state-of-the-art theoretical studies. When they are, then collaboration between student and teacher is carried out using faxes, email, document exchange, and phone calls.

Computational projects are also relatively easy to conduct at a distance. The very fact that the projects are based on computers, which in turn are usually connected to the Internet, makes communication simple. In addition, while it is preferable, students do not need to be as familiar with the underlying physics to develop algorithms associated with a computational project. The obstacles associated with these types of projects are more associated with ensuring connectivity of all of the participants, the availability of similar platforms to all of the participants, and the interoperability of code at all locations. These problems are not unique to distance education, but are rather a general problem faced by any research collaboration spread over various institutions. Exposing students to these challenges helps prepare them to deal with these problems when they encounter them later in their careers.

Experimentation is the most difficult type of research project to carry out over a distance. Frequently the goal of involving students in an experimental research project is to give them experience working directly with the equipment: constructing, troubleshooting, and maintaining the apparatus associated with the experiment. Combined with this, experimentation frequently requires a more extensive infrastructure to support it, ranging from hand-held tools to clean rooms and machining capabilities. While these challenges can be overcome by planning to bring distant students to the primary campus at various intervals, a viable general solution is currently unknown. Because of this, the focus of experimentally based research at a distance is on remote instrument control, data collection, and data analysis. Many of these techniques are being developed by the research community as a general tool, so their adoption in a student research experience does not represent a difficult leap.

A class of research that is not normally encountered in physics, but which plays an important role in other disciplines, is field work. This can involve collection of samples (as would happen in a biological or paleontological project), excavation of a site (archaeological or geological projects), or use of an archive (historical or literary project), among others. In these cases, travel to the site is an inherent part of the project. Expanding the travel to include students from other campuses is relatively straight-forward and becomes a simple exercise in coordination. As with the previously discussed projects, this problem is not unique to the educational experience, and so provides the students with exposure to a problem, and its solution, that they will encounter as a professional in their field.

The TECP carried out one research project during the four years it was funded. This was a computational project and involved students at WTAMU, TSU, and TAMUCC while the faculty member was at TAMUK. The lack of other projects has been connected to the unexpected problems of relatively few students interested in carrying out research combined with the lack of support to entice more students into projects. To counter this, at least one of the programs in the TECP has implemented a research course that is integrated into their degree plan.

Assessing the TECP

Assessing the impact of its programs is becoming a standard requirement of a department. It does not matter if the department is local or distributed. In the case of the distributed department, however, the impact of non-locality on the courses must be measured in addition to the traditional feedback. Also, the overall success of the distributed department concept needed to be assessed. As a result, a two tiered approach to assessment was set up.

The first tier looked at the impact of non-locality on the TECP courses, while the second tier considered the success of the distributed concept as a whole. For the first tier assessment, student surveys were created by the assessment team at Texas A&M University. Near the end of the semester, faculty were asked to provide student contact information to the assessment team, who in turn requested their feedback through the surveys.

Student evaluations were developed as an on-line process during the 2001–2004 years at Texas A&M University using an intermediary for assurance to students of anonymity. The evaluation questionnaires were made available for web development, but this aspect could be better instituted now due to improved technology for such activities. The limitation is that there are no real resources for web development activities for the TECP department. Sample questionnaires that were used by students can be obtained from the authors. Table 1 provides a summary of student responses from the 2005–2006 academic year. The three years of student evaluations did not indicate particularly vexing problems in the TV-web methods of course presentation. There were consistent issues for off-site students gaining access to expert help with problems when instructors were not available. These are not in principle different from any web-based or Interactive TV-based courses widely offered by many institutions. Specific results of focused assessment included:

The second tier considered the success of the distributed concept as a whole. This was accomplished through student and faculty surveys. A sample of the faculty survey can be obtained from the authors. Faculty evaluation included responses both by TECP faculty and by their colleagues at their respective universities. Specific topics asked of colleagues of the TECP included awareness (100% yes), recommendation that their students take a TECP course (100% yes), and interest in further knowledge about the TECP programs (100% yes), total faculty response number was 16. TECP faculty responded to a periodic end-of-year

Table 1 Summary of 18 student evaluations of 5 online courses for the 2005–2006 academic year

Question	Response
Technical issues	
The Internet component of the course was useful to me	4.0 ± 0.7
The TTVN component of the course was useful to me	3.7 ± 0.8
The Study Log component of the course was an effective way to measure student effort	2.0 ± 1.1
The textbook was appropriate for the course content	3.7 ± 0.8
Technical difficulties experienced during the semester interfered with my learning the material	2.3 ± 1.0
The Announcements posted in the course were clear and timely	3.7 ± 0.8
The Syllabus page on the Internet was useful to me	4.3 ± 0.4
The Course Outline page on the Internet was useful to me	4.3 ± 0.4
The Introduction section of the Internet course was useful to me	4.0 ± 0.5
The course was divided into appropriately sized Units with appropriately arranged contents	3.0 ± 0.6
The Review Problems at the end of each unit were useful to me	4.3 ± 0.4
The navigation bars at the top and bottom of each page made navigation easy	4.0 ± 0.4
I liked the way the material in the course was arranged in a tree structure with the easier material at the bottom of the tree	3.0 ± 0.7
I liked the way questions were inserted into the early material with immediate feedback on the answers	4.3 ± 0.4
General course issues	
The instructor presented the material in a clear and organized manner	3.0 ± 0.6
Assistance was available on my campus for physics problems or projects	4.3 ± 0.4
The instructor was available for assistance on physics problems or projects	3.0 ± 0.5
The instructor was considerate of students during class	4.3 ± 0.3
The instructor was enthusiastic about the subject matter of the course	3.7 ± 0.5
The instructor was knowledgeable about the subject matter of the course	4.3 ± 0.4
The tests covered material of the course appropriately	4.3 ± 0.4
The course requirements were ____ for the credit hours given (1. too little work 2. about right 3. too much work)	2.7 ± 0.3
For me this course was _33%_ elective _67%_ required	

1 = Strongly disagree, 2 = Disagree, 3 = Uncertain, 4 = Agree, 5 = Strongly agree

evaluation. While responses varied somewhat from year to year (typical number of respondents was 6), most faculty felt comfortable with Internet activities (83%) in their class (recall that there was less Internet usage at the earlier stages of this program), 67% felt the Internet component was useful for the course, 100% felt the television interaction was useful, none felt technical difficulties interfered with student learning, and all felt that Internet postings of syllabi, announcements, introductions, and related materials were at least moderately useful. TECP faculty were in agreement that the distributed department should be formed (early evaluations) and maintained (later evaluations). TECP faculty were unanimous in rejecting a "course only" mission for the TECP, felt the TECP improved camaraderie among faculty, but were ambivalent whether the TECP had a "department feel."

Overall, the TECP successfully created a distributed physics department that offers courses, research opportunities, and other standard features associated with an academic department. Recognition by the university system within which it operates was not completed by the end of the project period, and remains an uncertain decision. Maintenance and expansion depend on continued institutional funding and external grants and contracts. Specific areas of focused assessment included:

Courses

A stable sequence of courses was developed over the TECP project period. The process has been reasonably consistent and a planning process for course offerings is available on the TECP website. The course offerings are comparable to other physics degree programs offered at single institutions.

The development of the advanced laboratory course was a required component of the original FIPSE project, and was accomplished. The requirement to distribute activities and materials across institutions was also successfully accomplished.

In order to assess retention of materials, pre- and post-tests were used. Each instructor was allowed to create their own test sets to evaluate the amount of student learning. Sample data from Quantum Mechanics is shown in Fig. 5. The dramatic increases in post-test scores indicate dramatic

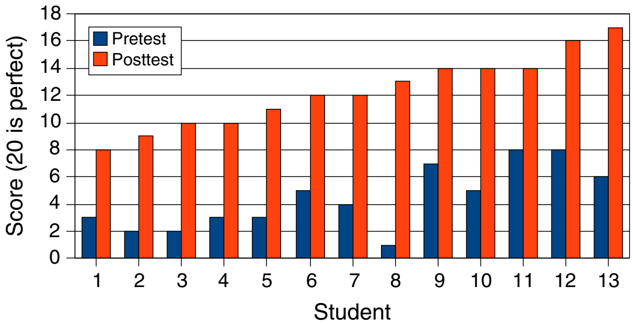

Fig. 5 Pre- and post-test results for Quantum Mechanics students from the Spring, 2004 offering

increase in students' proficiency in this senior-level course. There is also anecdotal evidence that all the students continuing into graduate programs have had no problems competing with others who came from traditional courses.

Training for Web-Assisted and TTVN Courses

The training process never developed adequately during the project's time frame. Changes in technology and personnel at the designated training center, WTAMU, seemed to limit the potential for this component to be relevant or significant to TECP operation. While some activities were conducted, it remains apparent that, as at many institutions, course development and expansion is at best ad hoc, poorly supported, and intermittent. In part this is a failure of higher administrations at all institutions to recognize the true costs associated with technology-mediated course and a concomitant assumption that such courses are cheaper than face-to-face courses. Most educational technology reports and papers suggest the opposite, that in fact they are at least as expensive as on-campus courses, if not more expensive, in total costs.

The TECP project made a good-faith attempt to standardize courseware and activities, and at least can be considered successful in continuing course offerings via the combinations of technology in use.

Laboratory Course Development

This component was perhaps the most difficult to develop, and TECP successfully produced a trial version of such a course. The various logistic aspects of attempting to conduct laboratory exercises and experiments across widely-spread institutions were overcome. Courses and activities such as this will be a major source of concern in the development of similar departments and course offerings elsewhere in science and technology programs. Increasing sophistication in communications technology, remote control, and remote sensing should make this task more manageable in the future.

Communications

The TECP department continued to operate primarily through email, with two face-to-face meetings per year, one each semester. Faculty communication increased over time as faculty worked to develop coordinated courses and commonly-agreed-upon curriculum content. The periodic TTVN meetings appeared to be helpful to department operations, although there were often technical problems in getting sites on-line. These sessions augmented the face-to-face meetings. Constant communication appeared to be an essential component of continued program development.

Website

The maintenance of the website was taken over by TAMUCC. The primary limitation has been the lack of dedicated resources to maintaining server hardware and to maintain and develop the website. This has been mostly an ad hoc process with support by TAMUCC on a limited basis and by TAMUK.

Through continued attention by two faculty members, Dr. Balasubramanya at TAMUCC and Dr. Suson at TAMUK, the server purchased through the project to provide communications for TECP was installed and the web site developed. As was noted in communications, the web function should be supported by either full-time or at least part-time dedicated staff, and that has not been accomplished. With that deficiency, the server is always at the mercy of TAMUCC regulations and requirements, is likely to become outmoded in a few years, and requires maintenance and upgrades that are now duties by faculty and students who can be put to those tasks when available.

The intent to use the server as the basis for course activities, materials, and communication has been partly met, but as noted above, without dedicated staff, remains only partly utilized as intended. Currently, participating institution servers continue to be used for course delivery and other TECP activities.

Course Enrollment

The practical difficulties remained during the project of making students aware of courses, due to various problems in individual institutions' course schedules. Student enrollment numbers for advanced courses remained and remains a continuing problem for small schools, but the TECP project demonstrated that if administrations are willing to tolerate small class sizes for advanced courses, such programs are viable. They are continually at risk, however, to administrative changes for minimum course size.

The accounting for tuition purposes of fees was managed through the inter-institutional MOAs mentioned earlier, and that process appears to have been working effectively for the institutions involved.

Research Opportunities for Undergraduates

This component was at best partially available during the project life, dependent on external grants to faculty at various institutions. This is perhaps not different from any similar institutional conditions for smaller universities. TSU and TAMUK appeared to have the most robust programs for potential student involvement. Additional engineering-related enrollment at those institutions greatly assisted the potential for undergraduates to be involved. TAMUK has a College of Engineering that provides additional students, while TSU has developed an Engineering Physics program that is attracting significant numbers of students. As discussed previously, only one distance-based research project was undertaken during the four years of the project, but local projects involving TECP faculty and students have been conducted at the majority of the institutions.

Department Meetings

Under the direction of Dr. Suson as department head, TECP has done a good job of maintaining department meetings via television or face-to-face meetings that have been more recently held in conjunction with various professional society meetings, as money for travel through the project was exhausted. Getting all participants at any one meeting has almost never happened, but that is probably not achievable under any situation and not dissimilar to faculty meetings within institutions. Several institutions had great difficulty maintaining consistent participation, although there were good-faith efforts to contribute. This was particularly acute at TAMIU at Laredo. The lack of a physics major there appears to have contributed to this.

Official Recognition and Institutionalization

One of the original questions to be addressed by the TECP project was the potential for expansion of the membership. The project had one significant experience, namely the proposed addition of Prairie View A&M University (PVAMU) into the TECP. After two years of discussion between TECP and PVAMU faculty, this attempt ended with PVAMU's withdrawal from the discussions.

The Prairie View A&M experiment highlights the difficulty of a program such as the TECP to add an established, large department to the concept of an electronic multi-institution program. PVAMU fundamentally did not need the TECP to generate advanced courses with sufficient numbers to be taught. While several PVAMU faculty were interested in the TECP, there did not appear to be widespread interest among the larger PVAMU faculty, nor by PVAMU higher administration. Ultimately, this resulted in PVAMU's decision to not participate in the TECP. It is also possible that concerns about generating and keeping credit hour production was an issue, correct or not, a typical institutional barrier to cooperation in a venture such as TECP. Interviews with PVAMU physics faculty were conducted by the project evaluator, revealing a problem with the perception of the structure of the Associate status, under which an institution could receive courses without having to participate further. Faculty did not see what was "in it" for them. There was also a sense that PVAMU did not need the TECP to maintain its program, nor would the courses taught by TECP necessarily benefit their students beyond what was already available.

The issue of institutionalization of the TECP program and recognition of the department as a TAMU System academic program was problematic during the entire development of TECP. While earlier in the project there appeared to be a "champion" for such a program at the Texas A&M System level, this never was realized. It was perhaps a communication problem for TECP, but also a problem of lack of higher administration leadership. The faculty in the TECP were never in a position to further institutionalization, and the low level of administrative involvement by deans of the various institutions, West Texas A&M University excepted, limited any potential for significant recognition and expansion of either TECP or other electronic coalitions.

Conclusions

Since 2001, the Texas Electronic Coalition for Physics has been operating as a distributed department. As such, it has served as a national model for how small programs can team together to maintain vitality. The TECP has developed equivalent methodologies for all of the traditional departmental functions. Among these are the

- management of course offerings to ensure that students are able to make optimal progress towards their degrees while ensuring that the classes are fairly distributed among faculty;
- establishment of an electronic office to facilitate departmental tracking functions;
- demonstration of the viability of carrying out research with students regardless of where students and faculty are located; and
- identification and use of technologies to maintain communications and esprit de corps.

Through these methods, the TECP has ensured that students at five different campuses are able to pursue an undergraduate degree in physics. Without the coalition, some of these programs would have ceased to exist, forcing these students to, at best, change institutions, or, at worst, change majors, and thus professions. In turn, this would significantly increase the time to degree for these students. By teaming together, the programs involved in the Texas Electronic Coalition for Physics have not only ensured that they can continue to serve the students at their respective institutions, but have charted a path that will enable them to grow into the future.

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