Appendix I.
Physics Education Resources

(compiled by Jose P. Mestre)

In this section we present a series of brief descriptions of recently developed materials for undergraduate physics. Each description was prepared by one of the authors of the materials. Each author also provided a series of written references and URLs for further information. The Task Force does not intend to endorse any of these resources over others that are not included in this appendix. These are the ones for which we received responses to a widely distributed solicitation within the physics community.

A. Physlets

Wolfgang Christian, Davidson College

The Physlet project is a synergy of curriculum development, computational physics, and physics education research. This project distributes a wide variety of class-tested interactive materials based on Java applets. Physlets employ a scripting language (JavaScript) to customize applets embedded within HTML pages, thereby allowing one applet to be used in many different contexts. This modular object-oriented software design enables Physlet adopters to easily author and customize their own interactive problems.

References

W. Christian and M. Belloni, *Physlets* (Prentice Hall, Upper Saddle River, NJ, 2001).

G. Novak , E. T. Patterson, A. Gavrin, and W. Christian, *Just In Time Teaching* (Prentice Hall, Upper Saddle River, NJ, 1999).

Website: *http://webphysics.davidson.edu/Applets/Applets.html*

B. Scale-Up

Robert Beichner, North Carolina State University

SCALE-UP stands for “Student-Centered Activities for Large Enrollment Undergraduate Programs.” We are adapting research-based pedagogies like collaborative, interactive learning so that they can be used in large-enrollment courses. This is done in a redesigned classroom environment of round tables and laptop computers where special classroom management techniques are utilized. Students are assigned to collaborative groups and spend most in-class time working on “tangible” (hands-on) and “ponderable” (“minds-on”) activities. The instructor and assistant(s) circulate and engage in Socratic dialogs with the students.

References

The precursor to SCALE-UP is described in R. Beichner, L. Bernold, E. Burniston, P. Dail, R. Felder, J. Gastineau, M. Gjertsen, and J. Risley, “Case study of the physics component of an integrated curriculum,” *Am. J. Phys.* (Phys. Ed. Res. Supplement) **67**, S16S24 (1999).

http://www.ncsu.edu/per/Articles/04IMPEC_AJP.pdf

Also see:

Robert J. Beichner, Jeffrey M. Saul, Rhett J. Allain, Duane L. Deardorff, David S. Abbott, “Introduction to SCALE UP: Student-Centered Activities for Large Enrollment University Physics,” Proceedings of the 2000 Annual meeting of the American Society for Engineering Education (2000).

http://www.ncsu.edu/per/Articles/01ASEE_paper_S-UP.pdf

J. Saul, D. Deardorff, D. Abbott, R. Allain, and R. Beichner, "Evaluating introductory physics classes in light of ABET criteria: An Example of SCALE-UP Project," Proceedings of the 2000 Annual meeting of the American Society for Engineering Education (2000).
http://www.ncsu.edu/per/Articles/02ASEE2000_S-UP_Eval.pdf

R. Beichner, "Student-Centered Activities for Large Enrollment University Physics (SCALE-UP)," Proceedings of the Sigma Xi Forum "Reshaping Undergraduate Science and Engineering Education: Tools for Better Learning," Minneapolis, MN (2000).
ftp://ftp.ncsu.edu/pub/ncsu/beichner/RB/SigmaXi.pdf

Scale-Up Website*: http://www.ncsu.edu/per/scaleup.htm*

C. Workshop Physics

Priscilla Laws, Dickinson College

Workshop Physics is a calculus-based introductory curriculum designed to help students understand the basis of knowledge in physics through the interplay between observations, experiments, definitions, mathematical description, and the construction of theories. Instead of attending separate lecture and lab sessions, they attend three 2-hour-long sessions each week to predict, observe, experiment, and use a powerful set of computer tools to develop graphical and mathematical models of phenomena. The curriculum is embodied in a 28 Unit Activity Guide published by John Wiley & Sons.

References

P.W. Laws, "Calculus-Based Physics Without Lectures," *Physics Today* **44** (12), 24–31 (December 1991).

P.W. Laws, *Workshop Physics Activity Guide* (John Wiley & Sons, Inc., New York, NY, 1997).

P.W. Laws, "Millikan Lecture 1996: Promoting active learning based on physics education research in introductory physics courses," *Am. J. Phys*. **65,** 14–21 (1997).

P.W. Laws, "A New Order for Mechanics," Proceedings of the Conference on the Introductory Physics Course, P.W. Laws and J. Wilson, eds. (John Wiley & Sons, New York, NY, 1997), pp. 125–136.

J.M. Saul, "An Evaluation of the Workshop Physics Dissemination Project" (U. of Maryland, 1998).

Workshop Physics Website: *http://physics.dickinson.edu*

D. Investigative Science Learning Environment (ISLE)

Eugenia Etkina, Rutgers University

Alan Van Heuvelen, Ohio State University and Rutgers University

In ISLE students use the processes of science to construct and apply knowledge. They observe simple experiments, make qualitative explanations and develop quantitative laws, and devise experiments to test and, if needed, revise the laws. The laws and models are applied for useful purposes to real-world applications. These processes of science investigation are integrated with the results of research about learning—active student participation, multiple representations of processes, and multiple exposures to concepts.

References

E. Etkina and A. Van Heuvelen, "Investigative Science Learning Environment: Using the processes of science and cognitive strategies to learn physics," Proceedings of the 2001 Physics Education Research Conference, Rochester, NY, pp. 17–21 (2001).

Websites:

http://www-rci.rutgers.edu/%7Eetkina/isle.htm

http://www.pt3.gse.rutgers.edu/physics/frontp.html

E. ALPS and ActivPhysics (Active Learning in Large and Small Classes)

Alan Van Heuvelen, Ohio State University and Rutgers University

The *Active Learning Problem Sheets* (the *ALPS Kits*) are paper-and-pencil activities that help students participate in learning in lectures and recitations. The kits include qualitative questions, multiple-representation activities, and problems done in a multiple-representation format. *ActivPhysics* is a comprehensive multimedia product that has similar activities as in the ALPS Kits with the added advantage of providing simultaneous simulated processes and dynamic representations of these processes.

References

Alan Van Heuvelen, "Millikan Lecture: The Workplace, Student Minds, and Physics Learning Systems," *Am. J. Phys.* **69,** 1139–1146 (2001).

Alan Van Heuvelen, Active Learning Problem Sheets: Mechanics and Electricity and Magnetism (Hadyn-McNeil, Plymouth, MI,1990).

Alan Van Heuvelen and P. D'Alessandris, *ActivePhysics I and II* (Addison-Wesley-Longman, Palo Alto, CA, 1998).

F. Matter and Interactions, Electric and Magnetic Fields

Bruce Sherwood and Ruth Chabay, North Carolina State University

The two-volume introductory calculus-based college physics textbook *Matter & Interactions* by Ruth Chabay and Bruce Sherwood (Wiley 2002) emphasizes the atomic nature of matter with macro-micro connections and engages students in modeling complex phenomena, including computer modeling. Analyses start from a small number of fundamental principles. Mechanics and thermal physics are treated as a single unified subject, as are electrostatics and circuits. The intent is to make introductory physics reflect the contemporary physics enterprise.

References

R.W. Chabay and B.A. Sherwood, "Bringing atoms into first-year physics," *Am. J. Phys.* **67,** 1045–1050 (1999).

http://www.wiley.com/college/chabay for the textbook, with a link from there to our own public website with additional materials, including free educational software. See *http://vpython.org* for the 3D programming environment developed for use with our curriculum.

G. Teaching Physics Through Cooperative Group Problem Solving

Ken Heller and Patricia Heller, University of Minnesota

Students solve Context-Rich quantitative problems that emphasize making expert-like decisions based on physics concepts. Student support includes teaching a general problem-solving framework and coaching using cooperative groups. This approach follows the Cognitive Apprenticeship paradigm of modeling, coaching, and fading. The modeling of desired problem-solving behavior is in lectures and in written problem solutions while coaching occurs in discussion sections and laboratories where the students work Context-Rich problems in cooperative groups.

References

P. Heller, R. Keith, and S. Anderson, "Teaching problem solving through cooperative grouping. Part 1: Groups versus individual problem solving," *Am. J. Phys.* **60,** 627–636 (1992).

P. Heller and M. Hollbaugh, "Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups," *Am. J. Phys.* **60,** 637–645 (1992).

P. Heller, T. Foster, and K. Heller, "Cooperative group problem solving laboratories for introductory classes," in E. F. Redish and J. S. Rigden, eds. *The Changing Role of Physics Departments in Modern Universities: Proceedings of International Conference on Undergraduate Physics Education* (American Institute of Physics, Woodbury, NY, 1996).

Website: *http://www.physics.umn.edu/groups/physed/*

H. Peer Instruction

Eric Mazur and Catherine Crouch, Harvard University

Peer Instruction engages students in class by asking questions that require each student to apply the core concepts being presented, and then to explain those concepts to their fellow students. Class consists of short lecture segments interspersed with a related conceptual question, called a ConcepTest, which probes students' understanding of the ideas just presented. Students formulate individual answers, then discuss their answers with others sitting around them for two to four minutes. Finally, the instructor calls an end to the discussion, explains the answer, and moves on to the next topic.

References

Catherine H. Crouch and Eric Mazur, "Peer Instruction: Ten Years of Experience and Results," *Am. J. Phys.* **69,** 970–977 (2001).

Adam P. Fagen, Catherine H. Crouch, and Eric Mazur, "Peer Instruction: Results from a Range of Classrooms," *Phys. Teach.* **40,** 206–209 (2002).

Eric Mazur, *Peer Instruction: A User's Manual* (Prentice Hall, Upper Saddle River, NJ, 1997).
Website: *http://galileo.harvard.edu/lgm/pi* (Note that this website requires free registration, so on your first visit, you get bounced to a login page which provides links to a registration area).

I. Just-in-Time Teaching (JiTT)

Evelyn Patterson, Air Force Academy

Just-in-Time Teaching (JiTT) is a teaching and learning strategy that exploits interaction between web-based study and an active learner classroom. Students respond electronically to carefully constructed web-based assignments due shortly before class, and the instructor reads the student submissions "just-in-time" to adjust the lesson to suit the students' needs. The heart of JiTT is the "feedback loop" formed by the students' outside-of-class preparation that fundamentally affects what happens during the subsequent in-class time together.

References

G. Novak, E. Patterson, A. Gavrin, and W. Christian, *Just-in-Time Teaching: Blending Active Learning with Web Technology* (Prentice Hall, Upper Saddle River, NJ, 1999).

Webreport: *http://www.pkal.org/pubs/Rothman.pdf*

"Then, Now, and in the Next Decade: A Commentary on Strengthening Undergraduate Science, Math, Engineering and Technology Education" publication which features JiTT on p. 18.

Webreport: *http://a-s.clayton.edu/henry/JiTT.htm*

Gregor Novak and Joan Middendorf, "Just-in-Time Teaching: Using Web Technology To Increase Student Learning," ISETA *Connexions* Newsletter **14** (1), (Spring 2002).

http://webphysics.iupui.edu/JiTT/CATE2000.doc

Gregor Novak and Evelyn Patterson, "The Best of Both Worlds: WWW Enhanced In-Class Instruction," in the Proceedings of the IASTED "Computers and Advanced Technology in Education" [CATE] 2000 International Conference, May 24–27, 2000.

JiTT website: *http://www.jitt.org or http://webphysics.iupui.edu/jitt/jitt.html*

J. Tutorials in Introductory Physics

Lillian McDermott, University of Washington

The Physics Department at the University of Washington has implemented a system of tutorials throughout the introductory calculus-based course. Beginning in 1991 with one lecture section in the mechanics portion of the course, weekly tutorials subsequently became an integral part of the entire first-year sequence, including the honors section. The instructional materials that are used in the 50-minute small sections have been published in *Tutorials in Introductory Physics.* The development of the tutorials has been guided by ongoing research on the learning and teaching of physics and includes continuous assessment through pretests and post-tests. Rigorous T.A. preparation and examinations that include questions on the content in the tutorials are essential for effective adoption. Although there is no direct evidence that the tutorials or the associated T.A. preparation are responsible, their inclusion in the department's instructional program correlates with a rise in the number of graduating physics majors to more than 50 in 2002.

The tutorials comprise an integrated system of pre-tests, worksheets, homework assignments, and post-tests. The tutorial sequence begins with a pre-test that helps students identify what they do and not understand about the material and what they are expected to learn in the upcoming tutorial. The pre-tests also inform the instructors about the level of student understanding. The worksheets, which consist of carefully sequenced tasks and questions, provide the structure for the tutorial sessions. Students work together in small groups, constructing answers for themselves through discussions with one another and with the tutorial instructors. The tutorial instructors do not lecture but ask questions designed to help students find their own answers. The tutorial homework reinforces and extends what is covered in the worksheets.

Post-test results, published in a number of articles, show a significant improvement in student understanding as a result of the tutorials. Furthermore, there has been no decrease in the ability of students to solve standard quantitative problems even though less time is spent in practice on problem solving. Results from pilot sites, ranging from two-year colleges to research universities, demonstrate that the tutorials work equally well in calculus-based and algebra-based courses.

Supported in part by the National Science Foundation, the development of Tutorials in Introductory Physics has been a collaborative effort by all members of the Physics Education Group at the University of Washington, past and present, with contributions by colleagues at other institutions. Leadership in the ongoing development of the tutorials is provided by Lillian C. McDermott, Peter S. Shaffer, and Paula R. L. Heron.

References

Lillian C. McDermott, Peter S. Shaffer, and the Physics Education Group at the University of Washington, *Tutorials in Introductory Physics* (Prentice Hall, Upper Saddle River, NY, Preliminary Edition 1998, First Edition 2002, and Instructor's Guide 2003).

For articles that discuss the motivation for the tutorials and provide an overall description, see:

L.C. McDermott, Millikan Award 1990, "What we teach and what is learned: Closing the gap," *Am. J. Phys.* **59** (4) 301 (1991).

L.C. McDermott, Guest Comment: "How we teach and how students learn—A mismatch?" *Am. J. Phys.* **61** (4) 295 (1993).

L.C. McDermott, Response for the 2001 Oersted Medal, "Physics education research: The key to student learning," *Am. J. Phys.* **69** (11) 1127–1137 (2001).

For articles that illustrate the research that guided the tutorials and describe some specific instructional strategies, see, for example:

L.C. McDermott and P.S. Shaffer, "Research as a guide for curriculum development: An example from introductory electricity, Part I: Investigation of student understanding," *Am. J. Phys.* **60** (11) 994 (1992); "Part II: Design of instructional strategies," *ibid*. **60** (11) 1003 (1992); Printer's erratum to Part I, *ibid.* **61** (81) (1993).

B.S. Ambrose, P.S. Shaffer, R.N. Steinberg, and L.C. McDermott, "An investigation of student understanding of single-slit diffraction and double-slit interference," *Am. J. Phys*. **67** (2) 146 (1999).

K. Wosilait, P.R.L. Heron, P.S. Shaffer, and L.C. McDermott, "Addressing student difficulties in applying a wave model to the interference and diffraction of light," *Am. J. (Phys. Ed. Res. Supplement)* **67** (7) S5 (1999).

The group's URL is *http://www.phys.washington.edu/groups/peg/.*

K. Classroom Communication Systems: Transforming Large Passive Lecture Classes into Interactive Learning Environments

Bill Gerace and Jose Mestre, University of Massachusetts–Amherst

How does one provide a pedagogically sound experience for students enrolled in introductory science classes at large universities, which are commonly taught in large lecture formats numbering from 100–400 students? An emerging technology, classroom communication systems (CCSs), has the potential to transform the way we teach science in large lecture settings. CCSs can serve as catalysts for creating a more interactive, student-centered classroom in the lecture hall, thereby allowing students to become more actively involved in constructing and using knowledge. CCSs not only make it easier to engage students in learning activities during lecture but also enhance the communication among students, and between the students and the instructor. This enhanced communication assists the students and the instructor in assessing understanding during class time, and affords the instructor the opportunity to devise instructional interventions that target students' needs as they arise. In short, CCSs greatly facilitate the instructor's ability to provide an active learning experience for students, to provide feedback to students on their learning, to accommodate different learning styles, to make students' thinking visible, and to provide instruction tailored to students' learning needs—all desirable instructional strategies based on learning principles described in a new report from the National Research Council titled *How People Learn: Brain, Mind, Experience and School.*

Classtalk and Personal Response System (PRS) are two CCSs being used extensively at UMass–Amherst. They are both a combination of software and hardware that permit the presentation of questions for small-group consideration, as well as the collection of answers and the class-wide display of a histogram of student answers. The display of the histogram is the springboard for a class-wide discussion of the ideas and methods used to analyze situations and solve problems. The time devoted to lecturing is decreased, while the time students devote to developing and refining their conceptual understanding is increased. The instructor's role, therefore, more closely resembles that of a coach than a dispenser of information.

CCSs are a tool, and by themselves do not contain any pedagogical components. The development of sound pedagogical strategies for using CCSs has been the focus of the Physics Education Research Group (PERG) at UMass–Amherst since 1993. UMass PER researchers have published articles on effective uses of CCSs in teaching introductory science (see below). In addition, PER members have conducted numerous workshops with UMass faculty to help them make the transition from student-passive, lecture-style instruction, to student-active, CCS-based instruction. Currently PER continues to provide ongoing technical and pedagogical support to instructors using CCSs in the Physics and Biology departments.

Thus far, 10 introductory courses across four departments at UMass (two courses in Sociology, one in economics, two in biology, and six in physics) have used CCS's to teach large introductory courses. In all cases, both instructors and students have had a very positive experience.

References

R.J Dufresne, W.J. Gerace, W.J. Leonard, J.P. Mestre, and L. Wenk, "Classtalk: A classroom communication system for active learning" *J. of Computing in Higher Educ.* **7,** 3–47 (1996).

J.P. Mestre, W.J. Gerace, R.J. Dufresne, and W.J. Leonard, "Promoting active learning in large classes using a classroom communication system," in E.F. Redish and J.S. Rigden, eds., *The Changing Role of Physics Departments in Modern Universities: Proceedings of International Conference on Undergraduate Physics Education* (American Institute of Physics, Woodbury, NY, 1997), pp. 1019–1036.

L. Wenk, R. Dufresne, W. Gerace, W. Leonard, and J. Mestre, "Technology-assisted active learning in large lectures," in C. D'Avanzo and A. McNichols, eds., *Student-active Science: Models of Innovation in College Science Teaching* (Saunders College Publishing, Philadelphia, PA, 1997), pp.431–452.

Website: *http://umperg.physics.umass.edu/*

L. Video Analysis in the Physics Laboratory

Dean Zollman, Kansas State University

Over the past 15 years video has become a common tool for analysis in the physics laboratory. When students collect data from an event recorded on video, they are using real events to help them understand how the motions are visualized. Interactive video aids students in understanding a variety of complex situations by enabling them to manipulate and measure variables. Data collection can be partially automated while nonlinear video provides flexibility in interactivity. Newer uses of video combined with simulation and modeling tools help students create visual but abstract models of physical processes. These methods provide new pedagogical tools for physics students and offer a much broader learning opportunities.

References

Dean Zollman and Robert Fuller, "Teaching and learning physics with interactive video," *Physics Today* **47** (4), 41–47 (1994).

Lawrence Escalada, Dean Zollman, and Robert Grabhorn, "Applications of interactive digital video in a physics classroom," *J. of Educ. Multimedia and Hypermedia* **5,** 73-97 (1996).

Lawrence T. Escalada and Dean Zollman, "An investigation on the effects of using interactive video in a physics classroom on student learning and attitudes," *J. of Res. in Science Teaching* **34**, 476–489 (1996).

Dean Zollman, "Millikan Lecture 1995: Do they just sit there? Reflections on helping students learn physics," *Am. J. Phys*. **64**, 114–119 (1996).

Teresa Larkin-Hein and Dean Zollman, "Digital video, learning styles, and student understanding of kinematics graphs," *J. of SMET Educ.* **1/1**, 4–17 (2000).

Priscilla Laws and Hans Pfister, "Using digital video analysis in introductory mechanics projects," *Phys. Teach.* **36,** 282–287 (1998).

Dean Zollman "Physics" in *Handbook on Information Technologies for Education and Training*, H.H. Adelsberger, B. Collis, and J.M. Pawlowski, eds. (Springer-Verlag, Berlin, 2002), pp 459–470. Kansas State University Physics Education Research Group: *http://www.phys.ksu.edu/perg/*

Vidshell 2000 (Doyle Davis), *http://webphysics.tec.nh.us/vidshell/clips.html*

VideoPoint, *http://www.lsw.com/videopoint/*

World in Motion, *http://members.aol.com/raacc/wim.html*
DAVID–Digitale Auswertung von Videos (in German)
http://www.physik.uni-muenchen.de/didaktik/Computer/DAVID/david.htm
Interactive Screen Experiments (in English & German), *http://bifrost.physik.tu-berlin.de/ibe/index.html*

M. Introductory Physics at a Large Research University

Gary Gladding, University of Illinois at Urbana–Champaign

The introductory physics courses at the University of Illinois at Urbana–Champaign have been completely revised in the last five years. The thrust of the revision was to integrate all aspects of a course using active-learning methods based on physics education research in a team-teaching environment.

References

The revisions are documented at:
http://www.physics.uiuc.edu/Education/Course_Revision.html.

A paper describing the project can be found at:
http://www.physics.uiuc.edu/Education/Course_Revision.html

N. RealTime Physics

David Sokoloff, University of Oregon and Ron Thornton, Tufts University

RealTime Physics (RTP) is an introductory laboratory curriculum for those desiring a complete, sequenced set of active learning laboratory activities for an entire semester or quarter, without changing the traditional course structure of lectures and labs. RTP is based on physics education research, makes use of a learning cycle of predictions, observations, comparison and conclusions, and focuses on conceptual and quantitative understanding. Microcomputer-based tools are used extensively, and computers are also used for modeling, data analysis, and simulations. The activities are written generically—using Experiment Configuration Files—so that they are not dependent on a particular hardware and software package. Module 1: Mechanics, Module 2: Heat and Thermodynamics and Module 3: Electric Circuits are published by Wiley. Light and Optics is under development.

References

Ronald K. Thornton and David R. Sokoloff, "RealTime Physics: Active Learning Laboratory," in E.F. Redish and J. R. Rigden, eds., *The Changing Role of the Physics Department in Modern Universities, Proceedings of the International Conference on Undergraduate Physics Education* (American Institute of Physics, Woodbury, NY, 1997), pp. 1101–1118.

Ronald K. Thornton and David R. Sokoloff, "Assessing student learning of Newton's laws: The force and motion conceptual evaluation and the evaluation of active learning laboratory and lecture curricula," *Am. J. Phys.* **66,** 338–352 (1998).

http://ase.tufts.edu/csmthttp://wiley.com/college/sokoloff-physics

O. Interactive Lecture Demonstrations

David Sokoloff, University of Oregon and Ron Thornton, Tufts University

Interactive Lecture Demonstrations (ILDs) are designed to enhance conceptual learning in large (and small) lectures. They are also useful in classrooms where only one computer is available. ILDs are based on physics education research, make use of a learning cycle of predictions, observations, comparison and conclusions, focus on conceptual understanding, and most make use of microcomputer-based laboratory (MBL) tools. The ILD procedure involves students recording individual predictions of the outcomes of simple experiments on a Prediction Sheet (which is collected), discussing their predictions with neighbors and then comparing their predictions to the actual results displayed for the class with the MBL tools. Interactive Lecture Demonstrations in Motion, Force and Energy are available from Vernier Software and Technology. ILDs in other areas are under development.

References

David R. Sokoloff and Ronald K. Thornton, "Using interactive lecture demonstrations to create an active learning environment," *Phys. Teach.* **35** (6), 340 (1997).

Ronald K. Thornton and David R. Sokoloff, "Assessing student learning of Newton's laws: The force and motion conceptual evaluation and the evaluation of active learning laboratory and lecture curricula," *Am. J. Phys.* **66,** 338–352 (1998).

Websites: *http://ase.tufts.edu/csmt and http://www.vernier.com/cmat/ild.html*

P. Studio Physics

Karen Cummings, Southern Connecticut State University

"Studio" teaching is a pedagogical approach rather than a specific curriculum. Developed and refined at Rensselaer between 1995 and 2002, the Studio approach integrates lectures, hands-on activities and instruction in problem solving in each class meeting. A premium is placed on student interactions within groups and with research-active professors. Extensive use of technology helps to make this approach effective in producing student learning and manageable for use at research universities.

References

For more information, see the references below or contact Karen Cummings at karen@rpi.edu or Jack M Wilson at JackMWilson@JackMWilson.com .

J. Wilson, "The CUPLE physics studio," *Phys. Teach.* **32** (9), 518–523 (1994).

K. Cummings and J. Marx, "Evaluating innovations in studio physics," *Am. J. Phys*. (*Phys. Ed. Res. Supplement*) **67** (7), S38-S44 (1999).

Q. Other Web Resources

Here we mention a few websites that offer collections of information on undergraduate physics and links to many other undergraduate physics web resources:

- The American Association of Physics Teachers maintains a website "Physical Sciences Resource Center," which contains much information and many links to other sources about undergraduate physics. *http://www.aapt.org*
- Project Galileo at Harvard University contains a collection of resources for undergraduate physics. *http://galileo.harvard.edu/lgm/pi*
- The large-scale digital library project comPADRE for physics is under development as of this writing (early 2003). Preliminary materials are expected to be ready through the AAPT website during the fall of 2003.

Appendix II.
Undergraduate Physics Reading List

(compiled by J. D. Garcia)

NTFUP's goals include encouraging awareness of the changing educational environment, promoting best practices in undergraduate physics education and providing mechanisms for greater dialog among physicists concerning undergraduate physics education. As a means of encouraging discussion and as a starting point for thinking about what has worked at various places, we have assembled an admittedly incomplete and selective set of articles and materials from the literature dealing with the teaching of physics and with physics education research. The resource letter on physics education research [McDermott and Redish, 1999] is a much larger bibliography on literature on the subject.

We encourage you to read this material and discuss it with your colleagues. These readings are intended to be only a starting point for discussions. Indeed, were we to include material on all programs, practices, and innovations that we deem worthwhile, the list would be prohibitively long.

Patricia Heller, Ronald Keith, and Scott Anderson, "Teaching problem solving through cooperative grouping. Part 1: Group vs. individual problem solving," *Am. J. Phys.* **60,** 627 (1992).

Patricia Heller, Ronald Keith, and Scott Anderson, "Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups," *Am. J. Phys.* **60,** 637 (1992).

William J. Leonard, Robert J. Dufresne, and Jose P. Mestre, "Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems," *Am J. Phys.* **64,** 1495 (1996).

Robert C. Hilborn, "Guest Comment: Revitalizing undergraduate physics—Who needs it?" *Am. J. Phys.* **65,** 175 (1997).

Edward F. Redish, "Millikan Lecture 1998: Building a science of teaching physics," *Am. J. Phys.* **67,** 562 (1997).

Eric Mazur, *Peer Instruction,* Chapter 2: Concepttests, (Prentice Hall, Upper Saddle River, NJ, 1997).

Lillian McDermott, "Bridging the Gap Between Teaching and Learning: the Role of Research," in *Proceedings of the International Conference on Undergraduate Physics Education,* CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 139–165.

Frederick Reif, "How Can We Help Students Acquire Effectively Usable Physics Knowledge?" in *Proceedings of the International Conference on Undergraduate Physics Education*, CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 179–195.

Rosanne Di Stefano, "Where an Instructor's Dreams Meet Reality: Total Available Student Time," in *Proceedings of the International Conference on Undergraduate Physics Education, CP399,* edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 225–239.

Ronald K. Thornton, "Conceptual Dynamics: Following Changing Student Views of Force and Motion," in *Proceedings of the International Conference on Undergraduate Physics Education,* CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 241–265.

Richard R. Hake, "Evaluating Conceptual Gains in Mechanics: A Six Thousand Student Survey of Test Data," in *Proceedings of the International Conference on Undergraduate Physics Education,* CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 595–603.

Fred Goldberg, "How Can Computer Technology be Used to Promote Learning and Communication Among Physics Teachers?" in *Proceedings of the International Conference on Undergraduate Physics Education,* CP399, edited by E.F. Redish and J.S. Rigden, (AIP Press, Woodbury, NY, 1997), pp. 2375–2392.

Richard Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys*. **66**, 64–74 (1998).

Lillian C. McDermott and Edward F. Redish, "Resource Letter: PER 1: Physics education research," *Am. J. Phys.* **67,** 755–767 (1999).

Ruth H. Howes and Robert C. Hilborn, "Guest Comment: Winds of change," *Am. J. Phys.* **68,** 40 (2000).

Corinne A. Manogue, Philip J. Siemens, Janet Tate, Kerry Browne, Margaret Niess, and Adam J. Wolfer, "Paradigms in physics: A new upper-division curriculum," *Am. J. Phys.* **69,** 978 (2001).

Edward F. Redish, *Teaching Physics* (John Wiley & Sons, New York, 2003).

Appendix III.
Presentations and Articles on SPIN-UP

A. Presentations

1. APS Meeting, Long Beach, CA, April 2000.

What's Happening in Undergraduate Physics Revitalization?
Robert C. Hilborn (University of Nebraska-Lincoln)

The American Association of Physics Teachers, the American Physical Society, and the American Institute of Physics have recently launched the National Task Force on Undergraduate Physics. The Task Force's initial activities are also supported by a planning grant from the Exxon Education Foundation. The goal of the Task Force is to coordinate a number of activities led by AAPT, APS, AIP and others to foster the "revitalization" of undergraduate physics programs across the country. The Task Force will also provide advice about new activities aimed at undergraduate physics. This effort emphasizes all aspects of undergraduate physics including the recruitment and mentoring of students, providing strong courses for physics majors, other science majors, nonscience majors and pre-service K–12 teachers, engaging students in research, and preparing students for a diverse set of careers. The Task Force focuses on the department as the fundamental unit for undergraduate education change while recognizing that innovations must be adapted to suit local needs. In this talk I will give some background of the events leading up to the establishment of the Task Force. I will also discuss some of the activities aimed at revitalizing undergraduate physics and plans for future programs under discussion by the Task Force.

2. AAPT Meeting, Guelph, Ontario August 1, 2000.

What's Happening in Undergraduate Physics Revitalization?
Robert C. Hilborn (Amherst College)

AAPT, the American Physical Society (APS), and the American Institute of Physics (AIP) have recently launched the National Task Force on Undergraduate Physics. The Task Force's initial activities are also supported by a planning grant from the ExxonMobil Foundation. The goal of the Task Force is to coordinate a number of activities led by AAPT, APS, AIP, and others to foster the "revitalization" of undergraduate physics programs across the country. The Task Force will also provide advice about new activities aimed at undergraduate physics. This effort emphasizes all aspects of undergraduate physics including: recruiting and mentoring students; providing strong courses for physics majors, other science majors, nonscience majors, and pre-service K–12 teachers; engaging students in research; and preparing students for a diverse set of careers. The Task Force focuses on the department as the fundamental unit for undergraduate education change while recognizing that innovations must be adapted to suit local needs. In this talk I will give some background of the events leading up to the establishment of the Task Force. I will also discuss some of the activities aimed at revitalizing undergraduate physics and plans for future programs under discussion by the Task Force.

3. APS Meeting, Washington, DC, April, 2001.

Building Undergraduate Physics Programs for the 21st Century
Robert C. Hilborn (Amherst College)

Undergraduate physics programs in the United States are under stress because of changes in the scientific and educational environment in which they operate. The number of undergraduate physics majors is declining nationwide; there is some evidence that the "best" undergraduate students are choosing majors other than physics, and funding agencies seem to be emphasizing K–12 education. How can physics departments respond creatively and constructively to these changes? After describing some of the details of the current environment, I will discuss the activities of the National Task Force on Undergraduate Physics, supported by the American Institute of Physics, the America Physical Society, the American Association of Physics Teachers and the ExxonMobil Foundation. I will also present some analysis of Task Force site visits to departments that have thriving undergraduate physics programs, pointing out the key features that seem to be necessary for success. Among these features are department-wide recruitment and retention efforts that are the theme of this session.

4. PKAL Summer Institute, Williamsburg, VA, June 2–5, 2002.
Brief presentation to all participants by Robert C. Hilborn (Amherst College).

5. AAPT/APS Physics Department Chairs Meeting, College Park, MD, June, 2002.

Report on Site Visits to Physics Departments
Ruth H. Howes (Ball State University)

6. NSF Physics, MPS, and DUE program officers, Arlington, VA, June 13, 2002.

Summary of SPIN-UP results presented by Robert C. Hilborn (Amherst College).

7. AAPT 2002 Summer Meeting, Boise, ID, August 5, 2002.

The National Task Force on Undergraduate Physics and SPIN-UP
Robert C. Hilborn (Amherst College)

The National Task Force on Undergraduate Physics, a joint effort of the American Association of Physics Teachers, the American Physical Society, the American Institute of Physics, and Project Kaleidoscope, was established in 1999 to provide advice to the physics professional societies and the physics community at large about the state of undergraduate physics. After reviewing some of the background leading up to the establishment of the Task Force, I will describe the project Strategic Programs for Innovations in Undergraduate Physics (SPIN-UP), a Task Force effort funded by the ExxonMobil Foundation. SPIN-UP focuses on site visits to about 20 colleges and universities that have thriving undergraduate physics programs and a survey, conducted in cooperation with AIP, of all undergraduate physics departments in the country. I will discuss the common features, identified from the site visits, found in departments that have thriving undergraduate physics programs.

The SPIN-UP Survey of Undergraduate Physics Programs
Kenneth Krane (Oregon State University)

In spring 2002, SPIN-UP (Strategic Programs for Innovations in Undergraduate Physics) of the National Task Force on Undergraduate Physics conducted (through the American Institute of Physics) a survey of undergraduate physics programs throughout the United States. Among the information that the survey form was designed to elicit were: (1) undergraduate curricula, including the character of the department's "standard" degree track and any alternative degree tracks that are available; (2) activities for recruiting undergraduate majors; (3) interactions between faculty and physics majors, including advising and mentoring as well as informal contacts; (4) alumni relations; and (5) curricular reform efforts. In addition to gathering information, the survey asked departments to evaluate the success of these activities and to discuss the current strengths and needs of the department. We will review the survey document and present the results analyzed to date.

Using the Results: Next Steps and Getting Involved
Ruth Howes (Ball State University)

SPIN-UP (Strategic Programs for Innovations in Undergraduate Physics) has studied the condition of undergraduate physics programs in all kinds of colleges and universities through site visits and a survey, the results of which have been presented in this session. We have focused on thriving departments with successful undergraduate programs. Not all undergraduate physics programs are thriving. The National Task Force on Undergraduate Physics is preparing to use the results of SPIN-UP to help other departments change constructively. We report on future plans and opportunities for AAPT members to become involved in improving undergraduate physics programs.

8. European Union Physics Departments Meeting, Varna, Bulgaria, September 7, 2002.

Presentation by Ruth H. Howes (Ball State University)

9. NSF-Corporate Foundation Alliance Meeting, Arlington, VA, October 23, 2002.

Presentation by Robert C. Hilborn (Amherst College).

10. Mid-West Physics Department Chairs Meeting, Chicago, November 3, 2002.

SPIN-UP Results and Analysis
Robert C. Hilborn (Amherst College)

B. Articles about the Task Force, and SPIN-UP and Related Activities.

"Revitalizing physics education," *Physics Today* **53** (4), 59–60 (April 2000). Brief notice about the formation of the Task Force.

"APS, AIP, and AAPT launch task force on undergrad physics," *APS News* **9** (4) (April 2000).

"The physics department 'Cosmo Quiz'," *APS News* **9** (4) (April 2000).

D. E. Neuenschwander, "What does 'Physics Revitalization" mean?" *Reveille* 2000.

Ruth H. Howes and Robert C. Hilborn, "Winds of change," *Am. J. Phys*. **68,** 401–402 (2000).

Robert C. Hilborn, "The National Task Force on Undergraduate Physics: Some FAQs," *APS Forum on Education Newsletter* (Spring/Summer 2000).

Carl Wieman, "A Modest proposal: Recruit undergraduate majors," *APS News* **10** (5) (May 2001).

Robert C. Hilborn, "The National Task Force on Undergraduate Physics," National Research Council Board on Physics and Astronomy *BPA News* (June 2001).

"Amherst Professor Hilborn to head National Task Force on Undergraduate Physics," *Amherst College Notes*, August 30, 2001.

"SPIN-UP seeks undergraduate programs to host site visits," *APS News* **12** (12) (December 2001).

Ken Krane, "What produces a thriving undergraduate physics program?" *APS News* 11 (11) (November, 2002).

Appendix IV.
Site Visit Volunteers

Mary Alberg
Seattle University

Teresa Burns
Coastal Carolina University

Ruth W. Chabay
Carnegie Mellon University
(now at North Carolina State University)

Cliff Chancey
University of Northern Iowa

Wolfgang Christian
Davidson College

Robert Ehrlich
George Mason University

William Evenson
Brigham Young University

Andrew Gavrin
Indiana University-Purdue University

Gary Gladding
University of Illinois

Kenneth Heller
University of Minnesota

Dennis Henry
Gustavus Adolphus College

Theodore Hodapp
Hamline University

Donald Holcomb
Cornell University

William Ingham
James Madison University

Patrick Kenealy
Cal State University Long Beach

Randall D. Knight
Cal Poly State University, San Luis Obispo

John Knox
Idaho State University

Jean Krisch
University of Michigan

Priscilla Laws
Dickinson College

Ramon Lopez
University of Texas El Paso

Catherine Mader
Hope College

Mary Beth Monroe
Southwest Texas Junior College

Kathie Newman
University of Notre Dame

Thomas Olsen
Lewis and Clark College

Richard Peterson
Bethel College

Rick Robinett
Pennsylvania State University

Lyle Roelofs
Haverford College

Warren Rogers
Westmont College

Richard Saenz
Cal Poly State University

James R. Sites
Colorado State University

David Sokoloff
University of Oregon

Patricia Sparks
Harvey Mudd College

Paul Stanley
California Lutheran University

Conley Stutz
Bradley University

Doyle Temple
Hampton University

Michael Thoennessen
Michigan State University

Ed Thomas
Georgia Institute of Technology

Jan Tobochnick
Kalamazoo College

Dean Zollman
Kansas State University

Appendix V.
Site Visit Documentation

This appendix contains the documents that were used in setting up and running the site visits.

A. Definition of a Thriving Undergraduate Physics Program

1. The number of majors is stable at a level that the department and the administration consider satisfactory or shows significant and sustained growth toward that number.
2. Morale is high for both faculty and students. They are engaged with physics, and the atmosphere within the department is collegial. Faculty regularly evaluate and respond to the changing needs of their students both majors and students in service courses, and work to enhance their skills as teachers. They seek to improve the experiences they offer their undergraduate students by constantly updating the departments' curriculum and by involving undergraduate colleagues in research.
3. Graduates find good jobs or obtain admission to graduate programs both in physics and in other fields. The department actively supports the professional development of its students by activities such as making information available about diverse careers, arranging for internships, or working with industries in an industrial advisory committee.
4. The college or university in which the department is situated respects the department, and all students find its programs attractive. Here "all" includes students enrolled in service and general education courses as well as physics majors and minors.
5. The department faculty work as a team to provide excellent undergraduate education. The majority of the faculty consider undergraduate teaching very important and honor their colleagues who do it even if they personally are not actively involved. The department invests resources not only in major courses but also in service and general education courses.
6. The department regards both undergraduate students and staff members as important members of the departmental team. Their voices are heard in making departmental decisions.
7. The department attracts and retains minorities and women as physics majors.
8. The department recognizes its responsibility to promote excellence in physics education for all K–12 students. This responsibility may be expressed through a variety of activities, for example: direct education of pre-service teachers; supportive involvement in physics or physical science courses or curricula for pre-service teachers (whether or not these courses are not taught by the physics department); in-service programs for local teachers; or outreach activities for local teachers and students.

B. Letter to the Site Visit Chair

Dear (Department Chair):

The purpose of the site visits of the National Task Force on Undergraduate Physics is to learn what makes a thriving undergraduate physics program. We are particularly interested in innovations in physics departments that could be widely duplicated. The site visits are supported by Strategic Programs for Innovations in Undergraduate Physics (SPIN-UP) through funding from the ExxonMobil Foundation.

The Task Force seeks to answer two questions:

1. What are the activities that position physics departments for **success** in producing more majors, placing graduates in a variety of interesting careers, and playing a productive and significant role in the academic life of the institution through both service courses, general studies courses, outreach programs, and so on?
2. What are the essential conditions within a department needed to promote a constructive and creative response to environmental change, and what events or pressures combined to stimulate those responses?

Some secondary (but important) issues:

Some departments have a large fraction of their faculty involved in innovating their undergraduate programs. However, many departments have only a small fraction of the faculty involved actively in undergraduate programs beyond routine meeting of classes. In this case, it is critical that other members of the department support them in such tangible ways as promotion and tenure. What is the minimum number of active faculty needed for excellence in an undergraduate program, particularly for making substantive changes? What support from the rest of the department is absolutely essential? How long does it take to produce lasting change within a physics department? How do the department and the institution measure success, particularly the effect of innovations, in the undergraduate program? How are the resources and faculty time needed to create a thriving undergraduate program balanced against other demands on the department and the faculty?

The documentation submitted by the department before the visit should provide data on what the department thinks it has accomplished. The site visit is needed to look for elements such as morale of faculty and students and institutional support that do not appear in formal reports. The visit is not intended to evaluate directly the strengths and weaknesses of the department's program. We do, however, want to achieve a realistic picture of what was done, how it was done, and how it is working. The eventual goal is to be able to characterize those elements that are important (or in some cases crucial) for planning, developing, implementing, and sustaining successful undergraduate physics programs. We must keep in mind that what constitutes a "thriving" program is subject to local interpretation though, of course, there will be many features common to all physics programs.

The attached contract explicitly states the terms under which the site visit will be conducted. Please sign it, return it to me, and keep a copy for your files. Also attached are several questions whose answers should be provided to the Task Force before the site visit. The Site Visit Team will consist of three physicists including one member of the Task Force. We will try to select members of the team from institutions geographically close to yours. Should you desire it, a member of the Site Visit Team will present a colloquium to your department. More information about the Task Force and its membership can be found on the AAPT website: *http://www.aapt.org/Projects/ntfup.cfm.*

The Task Force appreciates your agreeing to participate in the SPIN-UP site visit program. Your contribution will help other physics departments design constructive responses to the changing environments in which they find themselves.

C. Contract

The Task Force makes the following agreement with the Physics Department at ___________:

The department will cover all local expenses (housing, meals and local transportation during the visit) for the three-member site visit team.

The department will make appropriate hotel reservations for the site visit team. SPIN-UP will cover all travel expenses for the site visit team.

The department will provide the site visit team with written responses to a set of questions about the department's undergraduate program at least two weeks prior to the site visit.

In consultation with the site visit team leader, the department chair will set up a schedule of appointments with small groups of faculty (both in the department and outside the department as appropriate), students (both majors and nonmajors and special groups such as engineers, pre-service teachers, etc.), clerical and technical staff, and administrators.

After the site visit, the site visit team will provide the department chair with a written report of the team's findings within three weeks of the site visit. The chair will have one week to correct factual errors in the draft and return it to the chair of the site visit team. The report in final form will be submitted to the department chair and NTFUP. The report is written for the department chair. The chair may share the report with other members of the department and with the institution's administration at the discretion of the chair. The Task Force will seek the permission of the chair before using any of the data in the report in a way that links the data directly to the department. The Task Force may ask for additional data and comments as it prepares a Case Studies document.

D. Departmental Questionnaire for Task Force Site Visits

The Task Force site visit will be much more productive both for the Task Force and for the department if the site visit team members have some information about the department in advance of the actual visit. Please provide the information described below. (If you have this information in a different format, for example, for a recent departmental review or self-study, please feel free to substitute that report for the format given below.) We emphasize that this visit is not a usual departmental review. We are interested in the steps you have taken to ensure that your department's undergraduate program is truly thriving. The site visit team wishes to collect data ahead of time and spend site visit time talking with faculty, staff, students and administrators.

1. Personnel information

Please list:

A. Faculty by rank and give years in service and a brief statement of research areas

B. The number of support staff, (for example, departmental assistants, lecture demo support staff, lab instructors, technical staff, machine shop staff, electronics shop staff, etc.) and indicate if these staff are full-time or part-time.

2. Information about students

Please list:

A. The number of majors you have by class (first-year, sophomores, juniors, seniors) and the number of majors you have graduated each year for the last 10 years. Any data you have on entering physics majors or enrollment by class for different years would be helpful, as would information on demographic characteristics of your students. (For example, do you have a large number of nontraditional or transfer students? How many minority or women students are physics majors? Do your students come from public schools? Rural schools? Private schools? Do you have any information on their SAT scores or their high school grade point averages? Have most of them taken AP physics?) You don't need to undertake major research for this questionnaire, but data on the characteristics will allow the SVT to acquire a clearer picture of your department.

B. The typical enrollments in each of the undergraduate courses offered by your department (precise figures are not necessary). It would be helpful to have a brief phrase describing each course and its primary audience. Alert us to any historical trends in the data.

C. Typical career paths for your physics majors. Roughly what fraction go directly into the workforce, to K–12 teaching, to graduate school, to professional school, etc. Again alert us to any historical trends in those data.

D. Research participation and TA opportunities for undergraduates in your department.

E. Other opportunities for physics majors outside the classroom (e.g. an active SPS chapter, a student lounge, tutoring, etc.)

3. Provide a brief narrative about your undergraduate physics program (including the program for majors and courses for nonmajors), particularly focusing on what you consider to be the most important components and novel features that you believe are particularly successful. We would also like to learn about how the department planned for and implemented innovative features and how they are being evaluated and sustained. The following questions should be addressed:

A. What changes have you made during the last five years to improve the experiences of undergraduate students in your department's program?

B. How did you make these changes? Specifically: Why did you embark on change?

C. How did you recruit faculty to work on the new programs?

D. How did you obtain resources to support change? What added resources were you able to obtain?

E. What evidence do you have that your department is thriving and that your activities produce success?

4. If you have other general information about your undergraduate program including recruiting brochures, course catalog information, course or faculty evaluation forms, and so on, we would appreciate receiving copies of that information.

5. What academic or psychological services (such as tutoring or help with test anxiety) does your department or your university provide to students? What services does your university provide to students that are particularly useful to your department? For example, some physics departments benefit greatly from the active recruiting programs of their colleges.

6. Does your department play a significant role in the preparation of K–12 teachers? Describe that role and the department's interactions with the school of education (or the appropriate group within your institution).

7. Please feel free to send along other information that you believe might give us a good picture of your department and its program.

E. Site Visit Protocol

Before the Visit:

The department chair and project directors agree on terms of visit. The chair returns signed contract to the project director who is coordinating the visit.

1. The project directors select a site visiting team (SVT) and coordinate dates with the department being visited. The SVT will consist of three people, one of whom will be a member of the Task Force. The project directors will inform the chair of the membership of the SVT, coordinate travel for the visitors, and assure that the department has made appropriate hotel and meal arrangements. The project directors will check with site visitors regarding special dietary and room arrangements. Two weeks before the visit, the project directors send each member of the SVT a packet of information about SPIN-UP.
2. The department prepares answers to a questionnaire given to the chair along with the contract and sends it to the project directors at least two weeks before the scheduled visit. The project directors distribute copies of the questionnaire to members of the SVT. The department will also supply copies of catalog materials and, at its discretion, copies of recent external reviews or self-study evaluations.
3. A week before the visit, the department chair sends the project directors a schedule of activities planned for the site visit that the project director then sends to the SVT.

4. Two or three days before the visit, the SVT should schedule a conference, call, or exchange email to identify issues and questions about the department.
5. If a colloquium by one of the members of the SVT is part of the visit, the project directors will ensure that the department receives a title in a timely manner.

It is essential that the site visiting team meet as a group before starting the visit. If possible, the team should plan to arrive in late afternoon and meet in the evening. Otherwise, a breakfast meeting should be scheduled. The department chair may be invited to attend all or part of this meeting. The purpose of this meeting is to discuss the written material and prepare a strategy for finding answers to questions that arise.

During the visit (which is expected to last about one and a half days), the SVT should meet with: the chair, the coordinator of undergraduate programs, faculty in circumstances where informal discussion is possible, at least two groups of undergraduate students (both majors and nonmajors), the dean or other appropriate administrator, key departmental staff, and others selected by the department. The number of formal presentations to the team should be kept to a minimum with all necessary factual information presented in the materials sent out before the visit.

At the end of the visit, the SVT should meet in executive session to discuss their report. If it seems appropriate, the SVT may meet with the chair to summarize their findings.

F. After the Visit

The chair of the site visit team appointed by the project directors is primarily responsible for drafting the team's report to the department chair and NTFUP. The initial draft should be circulated electronically to the SVT for comment and correction and then (within three weeks of the visit) sent to the department chair for correction of factual errors. The department chair will then have one week to respond with reports of errors or omissions. The report should be in final form and submitted electronically to the SPIN-UP project directors and the department chair not more than one month after the visit. The project directors will share the report with the members of NTFUP who are asked to keep it confidential.

G. Sample Schedule

National Task Force on Undergraduate Physics
Visit to Colorado School of Mines Physics Department
October 5–6, 2000

Thursday Oct. 5

8:30: Meeting with Dept. Head (Prof. McNeil, Room 325)

Greetings/Orientation

9:00: Meeting with Pres. Trefny — Institutional perspective

10:00: Tour of department and review of data (McNeil)

11:00: Meeting with Freshman/Sophomore Physics majors (Room 347)

12:00: Lunch (Table Mountain Inn with Physics faculty)

1:30–2:30: Meeting with Junior/Senior Physics Majors (Room 347)

2:30–3:30: Meeting with half of physics faculty (Room 335)

3:30–4:30: Meeting with other half (Room 335)

7:00: Dinner (240 Union with Physics faculty)

Friday Oct. 6

8:30: Task Force team meeting (Room 335 will be available, if needed)

9:00: Meet with D. Williamson (previous Head)

10:00: Exit interview with Dept. Head (Room 325)

Appendix VI.
Formative Evaluator's Report

Developing a Framework for Creating Thriving Physics Departments:
A Report to the National Task Force on Undergraduate Physics

by

Charles R. Payne

Introduction

Over the past 10 years, the number of physics majors in university physics departments has been steadily declining. The reasons for the decline are readily apparent. According to Krane, Department of Physics, Oregon State University, the decline in undergraduate physics enrollments in the 1990s has been well documented.

> The number of baccalaureate physics degrees awarded per year in the United States dropped by about 25%, from about 5000 per year in 1990 to about 3800 per year in 1999. Simultaneously, the total number of bachelor's degrees was *increasing*, from about 1,000,000 per year to 1,200,000. During this period, the fraction of physics degrees awarded thus fell from 0.5% of total bachelor's degrees to 0.3%. Although there is perhaps evidence of a small uptick in the data for the past year or two, it is not clear that this represented a trend and even less clear that it can be sustained to reverse the decline of the past decade.

To respond to the issue of the decreasing number of physics graduates, an 11-member National Task Force on Undergraduate Physics (NTFUP) was formed in 1999 under the joint sponsorship of the American Physical Society, the American Association of Physics Teachers, and the American Institute of Physics. NTFUP is a group of physicists who are befitting of the term a "community of learners." They are well organized in that there appears to be representation from all of the major physics organizations. Among its members are two Noble Prize winners, physics department chairpersons from leading institutions, and other well-known physicists. As one would surmise, NTFUP is a very politically astute group.

The NTFUP studied how the environment has changed for undergraduate physics programs. They also investigated the constructive and innovative responses that departments have taken toward the changing environment. NTFUP operated on the assumption that the primary cause of the decline in the number of physics majors is due to the changes within the environment. They also believe that if physics departments are to thrive, then the physics community must respond to the changes. In his essay, "What Produces a Thriving Undergraduate Physics Program," Krane discussed the issues related to the decline in enrollment of undergraduate physics programs.

Although physics graduates are declining nationwide, a few physics departments can be described as thriving. At the request of the department chairs of 21 thriving departments, visitation teams consisting of three physicists were formed to visit these departments. The visits lasted on the average of one and a half days. Each team wrote a summary report of their visit. A framework for producing a thriving department was developed inductively from observations of common themes found in the reports.

A. Credibility of the Framework

The framework of a thriving department was arrived at inductively by extracting data from the reports of the 21 visitation teams. The framework is described as general characteristics, similar trends, and common themes of thriving physics departments. Although some team members visited more than one department, a total of 54 different physicists were involved in the visitations. The large number of highly trained physicists who made similar observations of thriving schools validated the reported observations and strengthened the reliability and validity of the framework.

The schools and the environments within which these thriving departments existed were very diverse. With respect to student enrollment and the number of departmental faculty members, the colleges and universities ranged from some of the smallest to some of the largest in the country. While all of the schools were recognized as quality institutions, it is salient to mention that some of these institutions were recognized as being among the country's most selective schools. The participating schools included private, public, and religious institutions as well as large urban and rural campuses. Geographical diversity was also represented in that most sections (East, Midwest, West, Northwest, and Southwest) were represented. The Southeast was the only geographical area that was not represented. These states included Alabama, Florida, Georgia, South Carolina, Tennessee, Mississippi, and Louisiana. It is also important to reiterate that the departments that participated in the visitations were identified as being successful in increasing the number of physics majors over the past few years.

Regardless of differences between the participating schools, essentially the same practices were being implemented in all of the thriving physics departments. From observations made by reading the reports, it has been concluded that there were certain practices common to all thriving physics departments. These practices are discussed below as key elements in the framework that other departments might be able to follow when attempting to change the departmental environment to be more inviting to students.

B. Elements of the Framework for Creating a Thriving Physics Department

A total of fourteen (14) elements were derived from the review of the reports. For the purposes of this report, each of elements will be listed and discussed in turn. The evidence that supports the element will also be provided along with reviewer comments where appropriate.

Element 1: Thriving physics departments have a reputation as being first rate in the types of academic programs that are offered, the pedagogical skills of the faculty, and the nurturing environment established by the faculty.

Evidence: The departments included in the visitations were chosen because they were going against the national trend of having a decline in the number of physics majors. All reports began with a description of the high academic quality of the undergraduate physics programs.

Comments: While it should be a given, it frequently has to be stated that "quality counts" when students choose academic programs. It is often the case when an academic department wants to increase the number of students involved in its program that the immediate fear of the faculty and the public is that the standards will be compromised. Nothing could be farther from the truth with regard to programs in these reports. The students who are attracted to the physics major are high caliber and very capable of determining whether or not they are receiving a high-quality education. They are also students who want to be challenged and they recognize when they are being challenged.

Of the 21 reports, there was only one instance where some members of the physics faculty intimated that quality was being sacrificed for the sake of increasing the number of majors. In this instance some of the faculty had negatively nicknamed one of the new courses "Light Physics."

Element 2: Thriving physics departments offer students both research opportunities and personal involvement with professors.

Evidence: All 21 physics departments indicated that they had research opportunities available for undergraduate students. While research conducted by undergraduates with the guidance of professors was strongly encouraged by all of the departments, approximately half of the departments made it a requirement. There was also a trend for departments that had not focused on undergraduate research opportunities in the past to become more active in making research opportunities for undergraduates more available.

Comments: Research opportunities were being made available in a variety of ways. For example, some of the smaller departments were encouraging their students to gain greater exposure by applying for Research Experiences for Undergraduates (REUs) at larger institutions during the summer. Other departments were beginning to fund their own research projects. All departments including those with the smallest number of faculty members offered some type of research opportunities and experiences for their undergraduate students. Quite often a senior research project was a capstone experience for undergraduate physics majors.

Element 3: Thriving physics departments have faculties whose reputations for having excellent pedagogical skills rank highly for attracting students into the major.

Evidence: It was frequently reported by visiting teams that students regularly commented on the pedagogical skills of the physics faculty. Students' comments were generally unsolicited and compared the physics faculty with faculty members in other departments. Some departments recognized a need for a change in pedagogy through a review of physics education research (PER). Departments also reported that they began to experience growth in the number of majors when the faculty began incorporating research findings from PER into classroom instruction. One of the schools developed an elaborate system to reward excellence in instruction for both faculty and graduate teaching assistants.

Comments: It has been a long-standing belief within the educational community that learning is determined by how people are taught, and that the quality of learning for any student is directly related to the quality of instruction. Excellent instruction, therefore, must be the premise for all changes. In addition, good teaching should be recognized and rewarded.

Element 4: Thriving physics departments have professors who serve, either formally or informally, as advisors.

Evidence: It was stated directly in 10 of the 21 departmental reports that physics professors served as academic advisors. Additionally, another 10 departments implied that the physics professors served informally as academic advisors. One department employed a person with a science degree to serve as an advisor, while only two departments made no mention of an advising component for physics majors.

Element 5: Thriving physics departments have goals that are clearly stated, are well known, and understood by the faculty and staff. The departmental goals are also consistent with the goals of each respective university.

Evidence: It was either directly or indirectly stated in each of the reports that the physics departments had goals that were aligned with the universities' goals. These departmental goals were clearly stated and understood by most faculty members. Visiting teams frequently met with administrators who expressed gratitude for the efforts of the physics department faculty in corroborating the goals of the university.

Element 6: Thriving physics departments actively recruit physics majors.

Evidence: Eighteen of the 21 departments reported some type of direct recruitment of physics majors. Seven of those departments reported having direct contact with and active recruitment in high schools. Three of the most successful physics programs, however, seemed to have a limited involvement with recruiting but were successful in attracting physics majors based on academic reputation alone. However, these same programs reported fostering a strong sense of community for physics majors.

Element 7: Thriving physics departments have departmentalized the practices that have been implemented to attract students. All departmental faculty members reported embracing the efforts that were put forth by a few of its members as valuable to the entire department.

Evidence: This was especially evident from the reports of three of the most highly successful programs. The problem with the lack of departmentalization was made very clear from one example of a department that described an aggressive and successful recruitment program; however, recruitment was done only by one individual. This was particularly problematic last year when this person was on leave and only half of the usual number of students chose physics as a major.

Element 8: Thriving physics departments foster environments where personal involvement of the faculty with individual students is the rule.

Evidence: Faculty involvement with students and their availability to students were elements that were observed in 100% of the departments. According to the reports, students readily responded to these faculties and expressed appreciation for their attitudes. Visiting teams, when describing faculty and student interactions, frequently used the expressions "sense of community" and "a community of learners." As reported by four of the visiting teams, the apparent positive effect that this type of interaction had on students prompted a comment such as the following: "Why can't other departments foster such an atmosphere?"

Comments: Involvement of the faculty was carried out in a number of ways.

An informal atmosphere where faculty are friendly with each other and accepting of students as members of the physics family.

All majors have easy access to faculty and departmental administration.

Majors are made to feel like they are part of the department and the physics endeavor.

Element 9: Thriving physics departments have flexibility in the physics curriculum.

Evidence: Flexibility within the physics curriculum was found to be the rule rather than the exception. Although there are a few departments that continue to hold on to the traditional physics curriculum, the trend is toward more flexible programs. For example, a number of departments have begun to offer a Bachelor of Science degree with fewer courses than the typical Bachelor of Arts.

Comment: There was great flexibility offered in the physics curriculum, but the most common pattern was a physics major combined with one of the other sciences; however, there were some unique combinations. It also appeared as though many departments had begun to reduce the physics requirements in order to accommodate a more flexible physics major. Of course this raised the issue of the standards of courses and programs being compromised. If a program meets the professional needs of a student by offering fewer courses, then it does not inherently lower the quality of the physics program.

Element 10: Thriving physics departments have strong institutional support both financially and academically.

Evidence: According to the departments, institutional support is provided for the physics departments in a number of ways. Some examples include the following: (a) funding undergraduate research projects; (b) supporting department chairs who made crucial decisions about implementing change; (c) granting permission to hire additional faculty; (d) supporting a more flexible physics curriculum; and (e) giving general praise and appreciation for faculty of the physics departments.

Comment: When an institution depends on its faculty to make major changes without financial assistance, it runs the risk of burning out the faculty. The possibility of faculty being over worked was raised in several of the reports, particularly in smaller departments.

Element 11: Thriving physics departments have a chapter of the Society of Physics Students (SPS) and/or other similar organizations.

Evidence: Seventeen departments indicated that they had SPS chapters. Although the activity level of the chapters varied, many of the departments gave high marks to the SPS chapters for creating a nurturing environment. The chapters were also responsible for many activities such as seminars, field trips, recruiting and other social functions. Six of the departments did not have SPS chapters; however, activities similar to SPS were carried out informally.

Element 12: Thriving physics departments are committed to undergraduate physics.

Evidence: All 21 departments indicated that they have made a commitment to undergraduate physics. For some departments, making this commitment was a major step toward creating an environment that would attract more majors. Several of the departments indicated that faculty made a conscious decision not to develop graduate programs but to focus on undergraduate physics. A common theme throughout the reports with regards to undergraduate physics was as follows:

> We learned that the entire faculty is involved in discussions of the undergraduate program at the department's faculty meetings, though revisions of particular courses or the development of new courses is often done by individual faculty members or a small group of faculty.

Element 13: Thriving physics departments have faculty members who are accepting and nurturing of students.

Evidence: The idea of a nurturing environment was a major thread that seemed to help establish bonds between students and faculty. Although departments used differing terminology, each addressed creating a nurturing environment. A representative categorization of one department is as follows:

a. Undergraduate majors get keys to the building and have access to a library, a computer area, and an informal "penthouse" area with a refrigerator, microwave, etc.

b. The physics building layout has faculty offices and labs in close proximity to classrooms and instructional labs. This fortuitous geographical layout encourages students to take advantage of the "open door" policy of most of the department's faculty members.

c. The department hires many of its undergraduates as lab and recitation T.A.s, research assistants, and computer assistants.

d. The students remarked that faculty members were willing to talk to them about anything, including questions dealing with materials in courses that the faculty member was not teaching.

Comments: A nurturing climate is the energy that makes the other elements of the framework successful. The success in implementing the framework is greater than just the sum of the elements. If the framework is to be successful, then there must be a genuine conviction and belief that the elements in the framework will make a difference in increasing the number of students who choose physics as a major. As one departmental faculty member stated, "warm fuzzes are not enough."

Element 14: Thriving physics departments have strong leadership.

Evidence: Although the word leadership may not have been used specifically within each department, department chairs and other administrators made strong inferences about leadership. Strong leadership was a key factor in assisting departments in changing the environment to attract a significant number of physics majors. In the majority of departments, most people were able to identify a specific person as a leader. This gave the impression of strong leadership through the change process.

C. Additional Concerns for Creating Thriving Physics Departments

After the review of the reports, it should be noted that there were several critical issues that were not addressed. Further, it seems appropriate for these issues to be of concern to NTFUP. Specifically, three (3) issues have been identified: (1) the preparation of high school physics teachers; (2) the educational preparation of women and minorities; and (3) the departmentalization of the elements for producing thriving physics departments.

First, there was little or no mention of interest in the preparation of high school physics teachers included in the reports. Of the 21 physics departments visited, 11 reported having some type of teacher education program; however, the comments about these programs made it clear that the preparation of high school physics teachers was not a focus for most physics departments. Two of the representative comments are as follows:

> [The] physics major is a very rigorous degree program and it is very difficult for students to major in physics if they are interested in teaching at the secondary level (although an occasional physics major does go into teaching).
>
> The department also has a Physics Teaching program that attracts one student per year. In addition, a few physics graduates join the Teach for America Program each year.

After reviewing the comments about the preparation of physics teachers, it seemed questionable about whether or not the maintenance and portrayal of the academic rigors of the major was at the expense of preparing people to use physics. It is also possible that the attitude about preparing high school physics teachers manifested the fear of lowering the standards of the major. If the number of physics majors is to increase at the university level, it seems unreasonable to expect that high school physics teachers can/will be able to prepare large numbers of potential majors if physicists are unwilling to teach the necessary content. Perhaps the physics community has recognized its negligence in preparing high school physics teachers because the NTFUP is piloting a nationwide PhysTEC Program, a very noteworthy effort for preparing high school physics teachers.

Although it might be issues of commitment, encouragement, and desire to do so, it should be pointed out that some departments already have the structure for producing high school physics teachers in place. The Masters of Arts in Physics Education (MAPE) that is offered by one of the departments already serves as a model program for assisting physics teachers who are already in the field.

The MAPE degree is designed to provide middle school physical science and high school physics teachers with a strong background in physics. The degree is designed for teachers who do not have an undergraduate degree in physics.

The physics education research and teacher preparation efforts of two other departments are also notable. But overall, only a few departments are showing concern about the preparation of physics teachers.

A second issue is that there was only an occasional mention of minorities and women in the departments, obviously not a strong point of emphasis. Again there are a few schools making a special effort to address this issue. Often when the issue of minorities is mentioned, it is assumed that the main concern is an issue of civil rights. To the contrary, this concern is for the future of physics and the acceptance that the perspectives of any given academic profession cannot rest solely with only one subgroup of the population—white males.

A related concern is the consideration of the white male subgroup of our society that the majority of physics majors come from, and whether this subgroup is increasing or decreasing in respect to its interest in physics. Due to the capabilities of the students in the present targeted pool, it is probable that they are excellent students not only in physics, but in other areas as well. Consequently, they will be attracted to other areas of study as well as recruited into other fields. If in fact potential physics majors primarily come from the subgroup of white males, then it is probable and conservatively estimated that 65% of the American population is not considered to be in the pool of potential physics majors. Further, if the U.S. demographic data continue as predicted, then the relative size of the pool of majors will continue to decline.

In one sense, finding a solution for the concern of increasing the presence of minorities and women in physics is related to the issue of preparing more and better high school physics teachers. More quality physics teachers in high schools will lead more potential physics majors to universities. However, finding a workable solution to the issue will be decidedly different from the issue of just preparing teachers. There are many sociocultural factors and barriers that must be overcome. The same elements of the framework will work for women and minorities, but there must be an understanding of cultural differences. More importantly, however, genuine attitudes of acceptance will remove barriers to learning. Credit must be given to NTFUP for its quick response in arranging a meeting scheduled for the fall of 2002 to begin addressing issues of diversity.

The third concern is a lack of departmentalization of the framework elements by many physics departments. The framework must become embedded within departmental policies, and the responsibilities for implementation must be shared by all faculty members. Although the term departmentalization was not specifically used in the reports, there was concern for the sustainability of practices once key people retired. This supports the concern that the framework needs to be departmentalized.

Summary

Concerned about the decline in the number of physics majors, members of the National Task Force on Undergraduate Physics (NTFUP) conducted a study to determine the causes of the decline and to determine strategies for reversing this phenomenon. Since not all physics departments have a declining enrollment in physics majors, NTFUP identified 21 thriving departments for study. To conduct the study, teams consisting of three physicists each visited the 21 physics departments for about one and a half days of observation. Each team summarized its observations and drafted a report. All reports were then examined to ascertain if there were any common themes that could possibly serve as a framework of elements for other departments to emulate. A framework consisting of fourteen (14) elements was identified as common to all thriving departments. Based on these elements, it appears as though there are practices that other physics departments can follow to increase the enrollment of physics majors.

There were also three concerns that might influence potential physics majors which were not mentioned in the reports but should be of concern to NTFUP. These issues are the lack of interest and focus in preparing high school physics teachers from many of the departments; the lack of minority and women representation in the departments; and the lack of departmentalization of the elements for producing thriving physics departments.

NTFUP is to be commended for its ability to take action by supporting PhysTEC, a nationally piloted program to increase the number of physics teachers and improve the preparation of high school physics teachers. Plans have already been made to begin addressing issues of diversity with a meeting for the fall of 2002.

Appendix VII.
Survey Form

The survey was administered as a web-based form. The following is a text version of the form.

National Task Force on Undergraduate Physics

Project SPIN-UP: Strategic Programs for Innovations in Undergraduate Physics
Sponsored by the ExxonMobil Foundation

SURVEY OF UNDERGRADUATE PHYSICS PROGRAMS

1. Your name: ______________________________

   Your title: ______________________________

   Your institution: ______________________________

   Email: ______________________________

Physics courses and curricula

2. How many total credits (not only physics) are required to earn a bachelor's degree at your institution? __ __ __ credits

Is your academic calendar divided into (check one)

___semesters? ___quarters? ___other?

What does "one credit" typically represent at your institution?

___ One hour per week in class

___ One course for an entire academic term

___ One course for an entire academic year

___ Other (please describe)___________________________________

3. Please respond below with information about your "most rigorous" physics program. This is usually the undergraduate curriculum that requires the largest number of physics credits and is often designed for students preparing for graduate study in physics. For this survey, we will refer to this program as your "standard" physics curriculum.

Degree title (check only one that gives the closest match with your "standard" program):

___ Bachelor of Science in physics

___ Bachelor of Arts in physics

___ Bachelor's in engineering physics

___ Bachelor's in applied physics

___ Other__________________________(please describe)

3a. How many credits are required in the following areas for this "standard" physics degree?:

_____ Physics credits

_____ Mathematics credits

_____ Chemistry credits

3b. Does this degree track **require** (check as many as apply):

___a research experience? ___a thesis?

3c. Total number of graduates (in this specific "standard" degree program) in past 3 years:
_______ (graduation years 1999, 2000, 2001)

4. Indicate below **the number of credits** in each area required for your "standard" degree program described in Question 3. The total should equal the number of physics credits you entered as a value in Question 3a.

____ Introductory classical physics (including lab, if appropriate)

____ Introductory modern physics

____ Intermediate classical mechanics

____ Intermediate electromagnetism

____ Mathematical physics

____ Optics

____ Thermal and/or statistical physics

____ Quantum mechanics

____ Advanced laboratory courses (including electronics)

____ Other physics courses

5. **In addition to** the "standard" degree program described in Questions 3 and 4, which of the following alternative degree tracks do you offer? Check the tracks at left, and also indicate the required number of physics credits and the total number of graduates in that track in the past 3 years (graduation years 1999, 2000, and 2001).

Below: First column: Number of physics credits required

Second column: total number of graduates in the past 3 years

___ Bachelor of arts (only if "standard" degree is *not* B.A.)	_____	_____
___ Engineering physics	_____	_____
___ Applied physics	_____	_____
___ Physics degree for teachers	_____	_____
___ Specialized degree or concentration (e.g., geophysics, biophysics, computational physics etc.)	_____	_____
___ Combined degree (e.g., physics + math, physics + business, etc.)	_____	_____

___ Astronomy degree (if offered through a separate department check here___) _____ _____

___ Other________________________ _____ _____

__________________________ _____ _____

___ None of the above

5a. Are you planning to add any alternative degree tracks in the near future? Please describe.____

____

____

6. Does your department or program offer a minor?

__ No __ Yes, in physics __ Yes, in astronomy

6a. How many **physics** credits are required for the **physics** minor? ___ credits

6b. How many students minored in physics over the past 3 years? ___

6c. How many students minored in astronomy over the past 3 years? ___

7. Averaged over the last 3 years, approximately **how many** of your graduating seniors participated in the following activities each year:

___ Undergraduate research on campus

___ Undergraduate research off campus (such as REU or industrial internship)

___ Presented research results at local, regional, or national meeting

Recruiting physics majors

8. Which, if any, of the recruiting activities below does your department pursue? Please check all that apply:

Recruiting of high school students:

___ Hold annual (or more often) departmental open house for students & parents

___ Host individual prospective students and their families in the department

___ Hold summer workshops for high school students

___ Faculty or students regularly visit local schools

___ Target recruitment of students likely to major in physics

___ Target recruitment of students who are underrepresented minorities

Recruiting of enrolled college students:

___ Identify and recruit talented students in service courses

___ Offer "introduction to the profession" courses for first-year students

___ Group potential physics majors in special section of the introductory course

___ Actively recruit transfer students from two-year colleges

___ Other (please describe) ____

8b. Please describe the recruitment activity or activities that you consider most successful in attracting majors to your department:____

____

____

Interactions between physics faculty and physics majors

9. Who has **primary** responsibility for advising physics majors?

___ Several or all physics faculty members

___ One physics faculty member (other than the department chair)

___ The department chair

___ A non-faculty physics department staff member

___ University advisors outside the physics department

___ Other (please describe) ____________________________

10. On average, how often do most physics majors interact with their advisor(s)?

__ Less than once per year

__ Once per year

__ Once per semester or quarter

__ Several times per semester or quarter

11. Which of the following does your department do for students? (*Check all that apply*)

__ Assign a faculty mentor to each student

__ Assign a peer mentor to each student

__ Provide dedicated undergraduate study room or lounge

__ Have an active physics club or SPS chapter

__ Provide building keys to undergraduate physics majors

__ Conduct exit interviews with graduating seniors

__ Other activities that enhance undergraduate program (*please describe*)

____

11b. Which (if any) of these activities does your department consider most effective in shaping student attitudes regarding your department? Please explain.

____

____

12. Which of the following have you used in the past year to provide career information to your undergraduates? (*check all that apply*)

___ Alumni visits to the department

___ Field trips to local industries

___ The university career services office

___ Departmental colloquia by physicists in industry

___ Career materials from the professional societies

___ Other (please explain) ________________________________

___ None of the above

12b. Which of these activities (if any) does your department find to be most useful in guiding your students' career choices?____

____

____

Alumni of the Department

13. What percentage of your alumni from the past three years have gone into the following areas?

Graduate study in physics	___ %
Graduate study in other area	___ %
Employment in technical field	___%
Employment in nontechnical field	___%
High school teaching	___%
Continued in a 3/2 engineering program	___%
Other	___%
Don't know	___%

14. What type of information does your department currently maintain on its alumni? (*Check all that apply.*)

___ Updates from past students by email or phone

___ Mailing or email addresses for students at the time they graduate

___ Information on employment or graduate school plans at time of graduation

___ Mailing list for departmental newsletter

___ Surveys of alumni

___ Other (please describe) ____

___ None of the above

Curricular reform

15. Have you made significant changes in your curriculum over the last several years?

___ Yes (*if yes, please continue to question 16*)

___ No (*if no changes were made, please skip to question 19*)

16. For each area in which changes were made, please specify whether the changes were made in content or in the way in which the courses are taught (pedagogy).

	Content	Pedagogy	Both	N/A
General education courses:	___	___	___	___
Algebra-based introductory course:	___	___	___	___
Calculus-based introductory course:	___	___	___	___
Introductory course for majors:	___	___	___	___
Upper-division courses:	___	___	___	___

17a. What motivated or prompted the curriculum changes? (e.g., threats from dean, energetic individual faculty member, external review committee, complaints from students, etc.) Please explain.

17b. What were these changes intended to accomplish? (e.g., increase introductory enrollments, increase number of majors, improve preparation of students for graduate school or careers, etc.) Please explain.

17c. What measures or indicators of success do you have for these changes? (If none, please state "none.")

18. How were the costs of these changes financed? (*Check all that apply.*)

___ Internal reallocation of resources within the department

___ University or endowment funds from outside the department

___ Grant(s) from private foundation(s)

___ Grant(s) from NSF or other federal agency

___ Funds or equipment from business or industry

___ Other (describe)____

19. What are your undergraduate program's greatest strengths?

____

____

____

20. What are your undergraduate program's greatest needs or challenges?

____

____

____

____

Appendix VIII.
Case Study Documents

The following pages contain the case study documents summarizing the findings of each of the 21 site visits. Each document is based on the report written by the site visit team. The chairs of the site visit departments have checked the documents for factual accuracy. The opinions expressed in the documents are those of the site visit teams.

The pdf version of this report, available through the American Association of Physics Teachers website (at http://www.aapt.org/Projects/ntfup/casestudies.cfm) has the case study documents with color pictures accompanying each document.

A. CASE STUDY: Angelo State University

The Setting:

Regional comprehensive university of 6,300 students. A majority of students come from the agricultural area around San Angelo, TX, a city of 100,000 where the university is located.

Enrollment is 25% minority (19% Hispanic, 5% Black, 1% Asian, and 0.3% Native American).

Department of Physics has eight full-time faculty (including a planetarium director and a geologist), two part-time faculty, and a departmental secretary. Student help is limited to a student tutor, a work-study student to help the secretary, and four students per semester to help with grading in large sections.

What Has Been Done:

1. The department offers three tracks to a bachelor's of science degree in physics as well as pre-engineering tracks in conjunction with other Texas universities.

   – The three major programs are physics, applied physics and physics with secondary certification. The department offers 3/2 Physics Engineering programs through articulation agreements with engineering departments at Texas A&M University, the University of Texas at El Paso and Lamar University. In addition, they have a 4/2 program leading to a masters degree in Semiconductor Physics or Semiconductor Engineering in conjunction with Texas Tech University.

2. The department has made a conscious decision not to pursue a graduate program in physics but to concentrate its efforts on undergraduate education.

   – The department has a unified sense of mission and focuses on high-quality education in small classes, and recruiting talented students. A particular focus is the preparation of students for careers in the health sciences.

3. The department cultivates a strong sense of community between students and faculty as well as within the student and faculty communities.

   – The SPS chapter is active and well-mentored. Entering students are encouraged to seek out upper classmen for mentoring and to join SPS. Students find the faculty accessible and perceive small classes as a great benefit of being at Angelo State. Students are advised on career goals and academic programs during pre-enrollment visits to campus, freshman orientation and as a part of regular advising periods. Each student is assigned a faculty advisor when he or she enters the university, and students cannot enroll for courses without permission from their advisors.

4. Student research is an important component of the ASU program and is characterized by the department as "the current capstone experience for majors."

   – Every physics major is required to complete a three-hour research course prior to the fall semester of their senior year, and the department typically has three to five students registered for undergraduate research per semester. More than half the faculty are engaged in research and the department has received more than $100,000 in funding to support undergraduate research. The Carr Research Fellowship, an internal funding source, also supports one to three students each year, and other students complete the research requirement through summer REU experiences.

5. The department has increasingly worked to recruit physics majors both in local high schools and in service courses.

   – The department makes annual recruiting trips to regional secondary schools, organizes on-campus programs for secondary students, and participates in college recruiting efforts. The department has several scholarships that are available to attract talented students.

Indicators of Success:

1. During the past 10 years, the department has graduated an average of eight students annually.
2. Approximately 1,400 students per semester enroll in physics, physical science, astronomy or geology giving the department the highest class size average (44 students) in the College of Science.
3. Several physics majors have recently completed medical school at prestigious institutions.
4. There appears to be a strong high school physics teacher bond and loyalty to Angelo State in recommending it to students.

Keys to Making the Changes:

1 The department benefited from long-term stability of faculty from 1960–1990 including both the Vice President for Academic Affairs and the President of the university as part-time faculty. Ten years ago, these faculty set about slowly and steadily hiring replacements who would be sensitive to the needs of Angelo State's students.

2. Department chairs have provided strong leadership in recruiting new faculty interested in teaching and research without fragmenting the strong student faculty cohesion that is a strength of the department.
3. The department works collegially with an unusually strong sense of shared mission. This shared mission is helped by the relative isolation of the university.

For More Information Contact:

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B. CASE STUDY: University of Arizona

The Setting:

A public, land grant, Research 1 institution with about 25,000 undergraduate students. The Department of Physics is administratively within the College of Science, which enrolls about 3,000 majors. Other physics-related programs in the College of Science include Astronomy, Atmospheric Sciences, and Planetary Sciences. The Optical Sciences Center is a world-renowned facility that independently offers undergraduate and graduate degrees in optics.

The Department of Physics includes 28 professorial faculty (seven assistant professors, one associate professor, 20 full professors) and two lecturers. The unusual distribution between assistant and full professors is a result of a number of retirements and an aggressive recruitment program to bring in new faculty. Major research programs in physics include AMO physics, astrophysics, biophysics, condensed matter physics, nuclear physics, elementary particle physics, and physics education. Two staff members have responsibility for the lecture demonstrations and the instructional laboratories.

Beginning in the 1960s and lasting through the 1980s, the university concentrated on building its reputation as a Research 1 institution and so focused its efforts on developing its research and graduate programs. In the 1990s, the Department of Physics, with strong support from the college and university administrations, undertook an ambitious program to strengthen its undergraduate program.

What Has Been Done:

1. In addition to its two traditional undergraduate degree programs (the standard physics B.S. degree and an Engineering Physics degree offered through the College of Engineering and Mines), the department has developed a B.A. degree and a B.S. in Science Education. The B.A. is intended for students who are interested in physics but not for professional careers (pre-law students, for example).
2. A separate option within the B.S. degree allows students to substitute courses in atmospheric science for certain physics courses and thereby achieve an interdisciplinary degree. Other such options are under consideration.
3. A diverse array of introductory courses is available, including those that serve biological science majors (both algebra-trig and calculus-based courses are available), engineering, and science majors. A separate four-semester course is offered for physics and astronomy majors.
4. A joint physics degree program for astronomy majors has been developed. This has increased the total number of physics graduates and has been especially effective in increasing the number of women physics graduates (because women generally constitute a higher fraction of astronomy majors than physics majors).
5. The department and the college have embarked on an ambitious program to train science teachers within the College of Science. Four new faculty positions were created (one in physics). A common and jointly taught set of teacher education courses has been developed.
6. There is an active program of reform in the introductory courses. Such techniques as peer instruction, interactive lecture demonstrations, and inquiry-based laboratories are being used.
7. The department maintains an exemplary outreach program, which includes enrichment activities for pre-college students and contacts with alumni such as a professional-

looking departmental magazine and a program that brings alumni back to the department for talks.

Indicators of Success:

1. The number of physics degrees awarded has remained fairly steady at about 22 per year despite the national decline. In addition an average of about six Engineering Physics degrees are awarded each year. About 25% of the degrees are awarded to women.
2. Even though many first-year students switch to other majors, the decrease is mitigated by a large number of students who transfer into physics or who enroll as double majors in the junior or senior year.
3. The department has been selected as one of the six initial sites to develop the PhysTEC program, which has been funded by NSF and the U.S. Department of Education.
4. Students appear to be very satisfied with the department and its programs and faculty.

Keys to Making the Changes:

1. The dean of the College of Science is very supportive of the department's efforts in undergraduate education and intends to support hiring to bring the department back to about 40 faculty.
2. The department head has made a significant commitment to improving the undergraduate program and has provided strong administrative support for faculty who are involved with the course improvements.
3. An active SPS chapter provides a unifying element for students. The department has provided the SPS with a laboratory room where students can work on their own to gain experimental skills and learn about the operation of laboratory equipment.
4. The department makes an effort to be open and accessible to students. The department head is accessible to students in his office and holds periodic "town hall" meetings with undergraduates. Students are asked to serve on departmental committees. The department has instituted a greater level of recognition for students who excel in their academic work.
5. A Science Education program has been developed within the College of Science to prepare K–12 science teachers; this program has stimulated reforms in the introductory courses.
6. The department involves many of its students in the research program and as undergraduate T.A.s.
7. An Academic Support Office in the Department of Physics helps students with schedule changes, arranges advising and tutoring, and provides information on scholarships and summer research opportunities. An employment database provides information on internships as well as on permanent positions.
8. Newly hired faculty are enthusiastic about the curriculum reform efforts. There is an active mentoring program for new faculty. A departmental teaching award recognizes outstanding accomplishments in teaching.
9. The department has funded a staff position as Communications Director to support the outreach programs.

For More Information Contact:

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C. CASE STUDY: Bethel College

The Setting:

Liberal arts college enrolling about 2,500 students founded by Swedish Baptists and retaining a strong Christian tradition. Enrollments are increasing and admission standards are gradually rising. The college accepts federal funding for faculty research but does not accept federal funding for activities solely directed towards instruction.

The department has recently expanded to four tenure track faculty members, has one adjunct faculty member and no staff although they use undergraduates as T.A.s for tutoring and lab assistance. Sixty majors enrolled in four physics tracks and a 3/2 program with an average of 12 graduates each year.

About a third of the graduates go to graduate school. Another third participate in the 3/2 engineering program; 8% become high school teachers, and the remaining quarter go directly into the workplace. Over the last decade, Bethel physics graduates have earned 16 Ph.D.s and another eight are currently Ph.D. candidates.

What Has Been Done:

1. The department is student-oriented, and faculty work to ensure that students are members of the physics family and know they are.

   – The introductory course is carefully taught to introduce students to the department. Majors from that class are recruited as T.A.s in their sophomore year so they know the next year's freshmen. Some upper-division courses are taught every other year so juniors and seniors work together.

   – The department provides keys to the labs to all majors, and any student who wants one has a desk in the labs or stockroom. Faculty are often in their offices nearby, even at night.

   – Each declared major is assigned a faculty advisor with whom they must interact at least twice a year. Any of the faculty can act as an advisor, and all work to keep students informed of opportunities like REU programs and internships.

2. The department encourages students' involvement in research. A research experience is required for the B.S. degree in physics.

   – Three weeks of the laboratory in each semester of the introductory course are devoted to student projects. With faculty guidance, student groups of three select projects, design and conduct the experiments, and prepare oral and written reports on them.

   – The optics course serves as an introduction to research in which students complete projects that are sophisticated enough for presentation in regional meetings and frequently serve as the basis for senior projects. Throughout the course, students are required to observe the forms of physics publications including preparing papers in laTEX with abstracts, data tables, graphs and photographs.

   – Faculty hire students in the summer as research assistants and encourage them to participate in REU experiences and internships in local industries.

3. The department accommodates the needs of its students by offering a B.S. in physics, a more flexible B.A. in physics, a major in Physics Education for preservice high school teachers, and a new B.S. in Applied Physics for students who plan to seek jobs in

industry or pursue graduate degrees in engineering or other interdisciplinary areas. They also have a 3/2 program in engineering in which about a third of their graduates are enrolled.

4. The faculty of the physics department have and work to maintain very close ties with local industries. Local industries employ students as interns and frequently hire graduates. Faculty work as consultants and have received support for research projects conducted at Bethel with student collaborators. Industries have donated state-of-the-art equipment to the department.
5. The department works to recruit talented high school students to Bethel through such means as hand-written letters and phone calls from the chair, presentations at local high schools, participation in summer programs for gifted students, and awarding of departmental scholarships.
6. The department has recruited talented retired high school teachers to design and teach a course for preservice elementary teachers. The course actively involves the teachers in doing physics and has been very popular and successful.

Indicators of Success:

1. The department graduates an average of 12 majors per year.
2. The department added a new tenure-line faculty position this year.
3. Since 1998, the faculty have published or presented 71 papers with 22 student coauthors.
4. About 10 students each year are employed as interns by local industries.
5. The college administrators consider the Department of Physics as a showcase department.
6. The students and faculty clearly work as colleagues, and alumni appear happy with the education they received at Bethel.

Keys to Making the Changes:

1. The faculty work extremely hard and are dedicated to their students and the college. The students reflect the faculty's work ethic.
2. The college administrators strongly support the work on the Department of Physics with both resources and faculty positions.
3. The Department of Physics has adequate funding for its programs from annual supply and equipment budgets, a $55 lab fee charged by the college, an endowment from a former professor, and outside research funding.
4. The department has worked to establish connections to the national and regional physics community both to improve the department's professional reputation and to provide their students with opportunities to participate in physics meetings.
5. Bethel College works to promote the growth of faculty members as scholars and teachers by careful mentoring and a five-year tenure review. This results in a very low faculty turnover, and the Department of Physics has benefited from this stability.

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D. CASE STUDY: Brigham Young University

The Setting:

A private, church-sponsored university with 32,000 students, 30,000 undergraduates. Ninety-eight percent of students are members of The Church of Jesus Christ of Latter-Day Saints; 50% are women and 10% are under-represented minorities. Most male students go on a two-year church mission after their freshman or sophomore years and are more mature than typical college juniors.

The Department of Physics and Astronomy has 28 full-time faculty [22 on Continuing Faculty Status (tenured)], two research associate professors, 10 full-time staff, and two staff who support commitments to the *X-Ray* journal and the Astronomical Society of the Pacific.

Teaching loads are 15 credit-hours per year and the department currently has about 25 graduate students. The department currently has almost 300 undergraduate physics and astronomy majors. Of current undergraduate majors, 46% are majoring in physics; 21% in astronomy; 14% in applied physics–selected options; 12% in applied physics–computer science; and 8% in physics teaching.

What Has Been Done:

1. For the past five years, all physics majors have been required to complete a senior thesis, honors thesis, capstone project or teaching experience before graduation.

   – Faculty mentor every student in one of these experiences. Two-thirds of the faculty advise undergraduate research projects which involve well over 100 student projects each semester. The university provides $20,000 per semester to support 20–25 undergraduate research students and the department and external grant funds support another 10 or so. REU funds support 10 undergraduates each summer although not all of them come from BYU.

2. The department has broadened and provided more flexibility in its degree requirements.

   – The department offers a standard physics major, a bachelors of arts for preservice teachers and an applied physics option. The applied physics option allows students to select courses from outside the department in areas such as other sciences, engineering, law, business or computer science and have them approved by the chair to complete their degrees.

   – The department as a whole has not adopted a single pedagogical style. However, faculty are aware of the results of Physics Education Research and have changed the way they teach in such ways as introducing more conceptual questions or using group work.

3. The department has expanded its advisement program.

   – The department has made advisors more available, hired student advisors and put them in highly visible locations, instituted an introductory seminar course, and improved the student handbook so that its style is welcoming to students and its content valuable and useful. Majors are encouraged to meet frequently with their advisors, and there is an on-call faculty advisor. The associate chair meets with students having difficulty to work out a plan to improve their performance. There are an undergraduate coordinator, an undergraduate research coordinator, a capstone project coordinator and a physics teaching coordinator who advise majors. Finally, research students are “adopted” into the group and get advice from the rest of the group. The system is well-publicized.

4. The department provides a nurturing environment for majors.

   – Faculty members are readily available for student questions during their time on campus. They treat all students with respect and dignity. The SPS chapter has become much more active drawing 40–100 students at activities, and there is an active astronomy club. All newly declared physics majors take a 1/2-credit hour course on “Introduction to Physics Careers and Research,” and students returning to school after their mission or another break are offered a one-credit hour course reviewing physics and math. The SPS space is integrated with the tutorial area which also houses the peer advisors. The department provides many non-research employment opportunities for students. The department maintains a “family” of alumni and has close ties with local schools.

5. The department views preservice and in-service education for K–12 teachers as an important part of its mission.

   – Faculty are working to involve students enrolled in the B.A. Physics Education option in more day-to-day activities in the department. They have a RET grant that supports four teachers each summer and are seeking funding for further activities.

Indicators of Success:

1. The department graduates 45–49 physics majors each year for the last three years, up from about 36 in the recent past. There is a high retention rate among majors, and students switch into physics from related disciplines such as math and engineering.
2. The number of freshmen physics majors has nearly doubled over the last 10 years; entering majors are increasingly better students and better prepared.
3. The percentage of female physics majors has increased from 19% between 1991–1996 to 26% over the last five years.
4. Ten percent of graduates enter teaching.
5. More than half of all graduates give papers on their research at regional or national meetings or conferences.
6. Graduates are accepted into quality graduate programs and recruited for jobs. Surveys of majors, alumni and graduating seniors reflect positively on the physics major program.

Keys to Making the Changes:

1. All faculty members are strongly committed to teaching and the excellence of the undergraduate program. The department and the university support this commitment with faculty time and dollars.
2. Changes in the undergraduate program come from suggestions made to or by the Department Undergraduate Committee and are presented to the faculty in writing and discussed and voted on by the entire faculty. The decision is usually by consensus as the department operated in a collegial manner. Faculty who suggested change usually volunteer to implement it.

3. Faculty have a high degree of collegiality and willingly collaborate in areas such as teaching, sharing equipment and sharing expertise. There is a sense of shared mission in the department.
4. The university administration tries to provide "top down support for bottom up ideas" and has been very supportive of the physics department's ideas for improving its undergraduate program in terms of resources as well as of moral support. Undergraduate research is one of the highest priorities of university fundraising.
5. An enrollment cap imposed by the Board of Trustees has increased the academic qualifications of entering students which has facilitated reform of the undergraduate physics program.
6. The sponsoring church contributes a unique environment to BYU including financial stability, support for scholarship by students and faculty, an unusual student body with common values and a strictly enforced honor code, as well as an edge in recruiting students who are members of the Church of Jesus Christ of Latter-Day Saints.

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E. CASE STUDY: Bryn Mawr College

The Setting:

Highly selective, liberal arts women's college with 1,200 undergraduates and 400 graduate students. It attracts very talented students who are culturally and geographically diverse and offers financial aid to more than half. 20% of students are of Asian heritage with a smattering of other minorities and foreign students.

The Physics Department has four tenure-line faculty members, a full-time laboratory coordinator who holds a Ph.D. in physics, two lecturers, one of whom has been at the college for four years and the second of whom is a sabbatical replacement, and a full-time departmental secretary. The department has access to a fully equipped machine shop, a library and state-of-the-art computer facilities. Teaching loads are five courses per year, and all tenure-line faculty are active in research.

The Physics Department at Bryn Mawr has a reciprocity agreement with nearby Haverford College. The two departments take turns offering upper-division physics courses which are open to students at both institutions. The department also has a small Ph.D. program that currently has four students enrolled. These students fulfill course requirements either as reading courses with Bryn Mawr faculty or by agreement with the University of Pennsylvania.

What Has Been Done:

1. The department works to create and maintain a family-like culture within the department. Their students are women, and the faculty work hard to build students' confidence in their ability to succeed in physics.

   – Students and faculty members are on a first-name basis. Student representatives attend faculty meetings and have a voice in departmental governance. The faculty work hard for the success of their students whether or not these students plan to attend graduate school in physics.

   – Physics majors are given building keys and keys to a "majors common room" and a computer lab. There is a kitchenette in the department, and students use numerous other rooms as study spaces. Students are provided with a handbook that is updated every year. All upper division majors have mail boxes in the department.

2. The major is designed to be flexible enough to accommodate the career goals of a variety of students. In addition, students who start physics in the fall of their sophomore year can complete a physics major in four years.

   – Two years of the major are completed at Bryn Mawr before students start upper division work, some of which is done at Haverford where most physics majors are male. This is a conscious decision to allow women majors time to gain confidence in their choice of profession.

   – Bryn Mawr physics courses are lab-intensive, and students are encouraged to work cooperatively as well as alone in order to maximize their confidence in their ability to manipulate equipment.

3. The department actively recruits as physics majors students enrolled in the introductory course. Faculty take considerable pains to encourage all students in the course and to point out to talented students that they could succeed as physics majors and the advantages that such a major offers.

4. The department stresses careful advising that works with students on all aspects of their

lives. One faculty member is assigned as chief advisor to students in one class and gets to know each student well. Faculty advisors actively seek students to be sure that they are encouraged to move forward in their chosen careers.

– The department is aware that only 40% of their majors will pursue a Ph.D. in physics and carefully advise the 29% who go directly into the workplace, the 9% who enter teaching, the 16% who plan to enter professional school, and the 7% who pursue masters degrees. The faculty track their alumni and are proud of their diverse careers.

5. Students are encouraged to participate in research. They are given tours of faculty labs in introductory courses and majors are invited to work with faculty in their labs. Because the faculty is small, students are also encouraged to participate in REU experiences at other universities, or take internships in industry or at national labs. A senior thesis is not a requirement for a degree, but students, particularly those planning to attend graduate school, are encouraged to complete one.

Indicators of Success:

1. The department graduates an average of 10 physics majors per year.
2. Morale among students is very high. They are proud of succeeding in a demanding curriculum.
3. Bryn Mawr is near the top of any list of colleges and universities in terms of production of numbers of women physics majors.
4. In recent years, 1–2% of the 150 women earning Ph.D.s in physics each year received their bachelor's degree at Bryn Mawr.
5. Nonmajors enrolled in service courses appreciate the supportive nature of the department, although they are not as enthusiastic as the majors about the laboratory experiences.

Keys to Making the Changes:

1. The faculty care deeply about their students and take their teaching role very seriously.
2. New faculty members immediately become members of the departmental team and are nurtured by senior faculty members.
3. The department works by consensus decisions of all faculty members reached through discussion at weekly faculty meetings which may include student representatives.
4. Faculty rotate administrative duties so government by consensus is very important.
5. The college administration has encouraged increasing the numbers of majors in disciplines where women are under-represented. The Admissions Office has actively recruited students who are interested in and capable of succeeding in science and mathematics, and enrollments in the sciences have increased across the board by 50% (except in chemistry).
6. Entering students generally have higher math SAT scores and lower verbal scores than students of 20 years ago, and there are currently a significant number of students of Asian background.

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F. CASE STUDY: California Polytechnic State University at San Luis Obispo

The Setting:

A comprehensive, four-year public university with 18,000 students whose philosophy is "learn by doing." Rated as the best public, largely undergraduate university in the West for the last nine years. One of three founding programs, the engineering program, has more than 4,500 majors.

The Physics Department of the College of Science and Mathematics has 30 faculty members, three technical staff members and two administrative staff. The department offers courses in astronomy, geology, geophysics, and oceanography as well as physics and offers B.A. and B.S. degrees in physics and the B.S. in physical science. The department graduates 15 majors per year of whom 25–35% go on to graduate school.

What Has Been Done:

1. The department has a tradition of being friendly and open with a broad, hands-on and can-do approach to physics.
   – The physics program is designed to be flexible, preparing students for graduate study in physics or related fields, a teacher-credentialling program, or work in industry. Students have the opportunity to participate in a wide variety of research programs.
   – Once students identify themselves as physics majors, they receive phone calls from a faculty member welcoming them into the department community and offering information and advice. The office staff actively helps physics majors in matters of enrollment and other academic details. The chair and most of the faculty are aware of the student community and actively foster it.
2. The department requires completion of a senior research project for all degrees.
   – A faculty member is assigned to help students formulate a project in one of the areas where the department has strength. The projects must involve creative and original efforts by the student and include traditional research projects as well as other types of projects.
3. The department has invested in a studio-style teaching laboratory which is not yet used for the upper-level majors' courses but has had an impact on faculty and student T.A.s who are involved in the course and the pedagogy is "leaking" into other physics courses.
4. The department has created a student-operated and controlled lounge area known as the h-bar ($\hbar$) which they describe as the "beating heart" of the physics program.
   – The h-bar is centrally located in the department, near faculty offices and space used by seniors for their research projects and is large enough to accommodate a large group or several small ones. Seniors feel responsibility to help younger majors, and the majors develop an unusually high degree of cohesiveness and have formed a genuine learning community. The h-bar is a home away from home for students but remains strongly focused on the work of the discipline.
5. The department has fostered the active and direct involvement of the technical staff in the educational experience of the students.
   – Many students interact directly with the technical staff, particularly during their senior projects, and staff see helping students as a part of their jobs. Students are required to complete five quarters of lab experience which include projects that are

student-initiated but completed under the guidance of an experienced technician. The friendly and respectful relationship between students and technical staff is a unique attribute of this program.

6. The requirements for retention, promotion and tenure are clearly and explicitly defined by the college in which the department resides. Younger faculty express appreciation of very clear guidelines, and this, in turn, provides an unusually stable environment for the department so that all faculty feel free to focus on the quality of instruction.

Indicators of Success:

1. The department graduates an average of 15 majors per year, a number that has recently been increasing.
2. Students perceive the faculty and staff of the department as friendlier and more open than other departments on campus.
3. There are a number of women active in the department and occupying leadership positions.
4. The selectivity of the department (and the university) and the quality of physics undergraduates has been increasing.
5. Graduates succeed in selective graduate schools and other careers.

Keys to Making the Changes:

1. Large enrollments in engineering offer a fertile recruiting ground for physics majors and the university has a tradition of strength in science and technology. The physics program has benefited as the university, helped by its high ratings in *U.S. News and World Report*, has attracted better prepared students.
2. There is an uncommon level of respect among all elements of the department: faculty, lecturers, administrative and technical staff and students.
3. Careful sequencing of classes fosters the development of student networking as does the provision of a student-controlled space in the department.
4. The pre-identification of majors encourages many physics majors to enter Cal Poly, and the fact that it is easy to identify majors in their first year allows mentoring of beginners by the department and fellow students.
5. The department and the administration encourage innovation in teaching from both the faculty and lecturers and the technical staff.

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G. CASE STUDY: Carleton College

The Setting:

An academically competitive, nonsectarian, liberal arts college with 1,902 students approximately evenly divided between men and women. It has historic strength in the sciences and mathematics and leads the liberal arts colleges in physics and astronomy graduates who obtain Ph.D.s in these fields.

The Physics and Astronomy Department has seven tenure-line faculty members, an instrument maker, an administrative assistant, and an electronics and laboratory manager. The department also employs a fifth-year Educational Associate who helps with the observatory and other astronomy equipment. There are currently 44 junior and senior majors.

In 1995, the department noted a significant drop in the number of declared majors. From 1993 to 1996, the department averaged 19 graduates per year. From 1997 to 2000, the average was 10.5.

What Has Been Done:

1. Instructors recruit physics majors during the introductory courses which are always taught by experienced and student-oriented faculty members.

   – Students at Carleton declare majors in the spring of their sophomore years after taking a number of courses in physics as well as other disciplines that interest them. Thus the department relies on the college's very able admissions staff to recruit able students and provide potential physics majors with information about these programs. They focus recruiting on the introductory physics courses and use them to develop a personal connection between students and a faculty member.

   – Carleton students take three courses for each of three terms. Each course is worth six credits and is equivalent to a semester-long course. The introductory physics sequence has two entry points, a three-credit course on Newtonian mechanics or a three-credit course on applications of Newtonian mechanics in the planetary realm aimed at better prepared students. The second three-credit course focuses on special relativity and particle physics topics few students have seen and which they find fascinating. Students are able to "sample" physics without committing themselves to a full year course.

2. The curriculum for physics majors is flexible and intended to integrate with a liberal arts education and prepare students for a variety of future careers as well as graduate and professional study in physics and other fields.

   – The former six-credit Classical Mechanics course has been split into two 3-credit courses, Classical Mechanics and Computational Mechanics, in order increase students' training in computational physics.

   – A required course on Waves was replaced by an applied physics requirement in which students select from a list of courses. This adds flexibility to the curriculum and allows students to spend a term off campus without getting out of sequence with the major.

   – Students are required to complete a senior "integrative exercise" in which they work with a faculty advisor to prepare a major paper and make an extended oral presentation on a topic chosen to integrate the physics they have studied in various courses.

3. The department works hard to build a sense of community among students and faculty in the department.
   – Students have keys to the physics building and a lounge as well as access to lab space and computers after hours. Pictures of all majors are posted in the lounge. Students and faculty have one or more meals together each week and may include visitors or speakers in them. There are organized social events including a spring and fall departmental picnic and a senior canoe trip.
   – After 7:00 p.m., the physics building belongs to students and typically eight to 10 of them can be found. They regard their fellow physics majors as an important element in their education.
   – The departmental curriculum committee consists of six students and two faculty members. When the numbers of majors dropped, the faculty listened carefully to student opinions.
4. The department encourages students to pursue a variety of careers through a course on "What Physicists Do" which brings five speakers to campus in a term to discuss their use of physics in diverse careers.
5. Students are encouraged to become involved in research with faculty some of whom have outside funding and all of whom remain active in physics. The college has funding to support some students during summer research projects, and all faculty work on research during the summer.

Indicators of Success:

1. The department graduated 16 majors in 2001 and currently has 26 seniors and 18 juniors who have declared physics majors.
2. Faculty and students both express enthusiasm for the community they find in the physics department.
3. Student morale is very high. Students participate in departmental decisions and feel ownership of their own education.
4. The administration respects the work of the department and is well-informed about its activities.

Keys to Making Change:

1. All faculty consider teaching their first priority, and promotion and tenure are based primarily on work in the classroom and interactions with students.
2. There is a strong personal interaction among faculty and students that centers on individual learning, growth and development.
3. The department has a shared understanding of its mission and an intense sense of purpose in fulfilling it. Decisions to make changes are made after open discussion by consensus of the faculty.
4. Students participate actively in determining curriculum and changes that should be made in it.

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H. CASE STUDY: Colorado School of Mines

The Setting:

A public research university with 3,000 students of whom 2,500 are undergraduates. Eleven undergraduate degree programs have expanded from traditional emphasis on mining to include energy, mineral, materials science, engineering, and associated engineering and science fields. Twenty-five percent of students are women and 15% are underrepresented minorities.

The Department of Physics has 14 tenure-line faculty, four adjunct professors, one research professor and two faculty members who are on phased retirement. One faculty member serves as laboratory instructor and lecture demonstration coordinator. Another serves as a full-time lecturer with no research responsibilities. The department also has a computer system administrator, an administrative assistant, a machinist and an electronics technician. The department awards three M.S. degrees and three Ph.D.s per year.

The undergraduate physics program, engineering physics, is one of 14 ABET accredited physics programs in the country. In 1996, the department established a five-year program leading to a B.S. in engineering physics and a masters degree in mechanical, electrical or electronic materials engineering. 20% of the department's majors are involved in the five-year program. All undergraduates take calculus-based physics as part of the core curriculum. One-third of graduates attend graduate school, roughly half in physics and half in engineering fields; a third take jobs in industry; and the rest follow a variety of paths.

What Has Been Done:

1. In 1984, the department decided to focus its program on engineering physics.

   – Requirements in the upper-level curriculum were reduced to allow students to take more applied courses although traditional upper division courses are available to students who need them. The department focused its research efforts on applied areas in nuclear physics, condensed matter physics and optical physics.

2. The department actively recruits students by emphasizing the flexibility of its programs and the wide range of careers to which they lead.

   – They provide a list of recent graduates and their current employment. The department participates in university recruitment days for high school students and their parents. During the required freshman seminar, physics faculty and students man posters at Options Days. The five-year program is advertised during the second semester of the required physics course. The department head assigns its best teachers to the large introductory sections.

3. The department teaches all students in the university introductory physics in sections of 90–100 students. Although students view the second semester of this course as one of the most difficult in the university, the faculty use this opportunity to recruit talented students as engineering physics majors.

4. The department works to build a community among faculty and undergraduate students.

   – Undergraduate majors have building keys and access to the library, a computer area, and an informal "penthouse" with a microwave etc. Faculty maintain an open-door policy, and their labs and offices are close to classrooms and instructional labs. The department hires undergraduates as teaching, research and computer assistants. There is an active SPS chapter.

– The department, like all at CSM, holds a six-week Summer Field Session devoted to lab techniques and an introduction to research in the department. The intense experience builds community among undergraduate majors.

5. The department recruits new faculty members who match the department's emphasis on undergraduate teaching and research. New faculty members are assigned a senior mentor. Junior faculty members have lunch with the department head almost every day. He evaluates all faculty members every year and provides constant feedback on progress towards meeting the goals of the department. He also holds exit interviews with graduating students in which he seeks evaluation on individual faculty members and courses as well as the program as a whole.

Indicators of Success:

1. The department graduates an average of 22 physics majors per year. The range is 16–28 majors per year and is expected to grow as incoming numbers are growing.
2. About 40% more majors graduate with a degree in physics compared to the number declaring physics majors on entering CSM and 20% of the majors are women.
3. The undergraduate engineering physics program is ABET accredited.
4. Students recognize and appreciate faculty concern for them and the sense of community in the department.
5. The department is known as "friendly," a reputation enjoyed by few other departments.

Keys to Making the Changes:

1. The department has a realistic and very clear sense of its mission that is aligned with the mission of CSM and which is reflected in hiring, in interactions with students, and in interactions with other departments.
2. The department has enjoyed strong leadership from heads who have been able to forge consensus on allocation of resources as the department has shifted its focus from pure teaching to emphasis on teaching and research and to retain emphasis on excellence in undergraduate teaching.
3. The department seeks advice from an outside "Visiting Committee," and from alumni.
4. The university, particularly the Vice President for Academic Affairs, provides resources to support curricular innovation.
5. Colorado School of Mines has an unusually narrow and well-defined mission which carries over to departments and facilitates activities that cross disciplinary lines.

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I. CASE STUDY: Grove City College

The Setting:

Medium-sized undergraduate college with 2,300 students affiliated with the Presbyterian Church. High admission standards and a reputation for offering students a challenging curriculum and keeping fees low. There is no faculty tenure and the college does not accept government funds.

The Department of Physics has five faculty members and no staff although they make heavy use of undergraduate assistants. Forty physics majors in three tracks with 10 graduates per year. Typically, 25% of majors are women.

The majority of graduates successfully seek employment immediately following graduation although a few go to graduate school. Teaching majors are especially sought after.

What Has Been Done:

1. Faculty members work to provide a collegial atmosphere in the department.
   – Faculty work closely together. Offices are clustered to promote informal interaction, and they meet for lunch once a week to discuss teaching and research.
   – Faculty know students well and join them in social events some held in faculty homes and some including alumni.
   – The department holds monthly meals for faculty and students at which students report on research done for example during a summer internship.
   – The department uses many student assistants both as T.A.s in labs and in other capacities so they function as junior members of the department.
2. The department designed and instituted a curriculum that serves the needs of Grove City students. It offers three tracks that lead to jobs or graduate school after graduation.
   – *The Applied Physics Track*: closest to traditional physics major but emphasis is on preparing students for the workplace as well.
   – *The Applied Physics/Computer Track:* replaces some of the advanced physics requirements with courses in computer engineering. Graduates are more attractive to employers than students with only computer skills.
   – *The Physics/General Science Secondary Education Track:* prepares students for careers in secondary teaching. Graduates frequently have multiple job offers on graduation. Physics requirements are kept lean to allow time for better preparation in other sciences and education.
3. The department does an excellent job in teaching service courses using results of PER as well as new technologies. Although physics is no longer required of all students, nonmajors continue to elect physics or astronomy as one of their science options.
   – The department is a campus leader in the use of computers in education. All Grove City students are provided with laptop computers and use them extensively in labs.
   – Eleven years ago the department introduced a nonmajor service course, Fundamentals of the Universe, which has improved the department’s reputation among students, faculty and administrators on campus.

4. The department works closely with the Education Department to provide graduates who are eligible for 7–12 certification in physics and general science.
   – The department uses education-track students to critique lectures in the introductory physics course, help with labs and teach study/review sessions, and even give a lecture in the course. They gain practical teaching experience while assisting the department.
5. The department focuses recruiting efforts on students already planning to attend Grove City because it has proved to be a more efficient use of their time and resources than recruiting high school students.
6. The department encourages students to obtain research experience during summers as interns or as participants in REU programs. They have recently begun to build in-house programs designed for student participation.

Indicators of Success:

1. The numbers of students graduating with bachelor's degrees has increased steadily over the last 10 years.
2. Faculty and students within the department work as colleagues.
3. The Physics Department is highly respected on campus.
4. Enrollments in service courses remain strong although physics is no longer a requirement.
5. Graduates on the education track are heavily recruited by school systems.

Keys to Making the Changes:

1. Faculty members in the department make decisions as a group and share a common vision of the department's mission as service to students not a training ground for future Ph.D.s.
2. Faculty members take the scholarship of teaching very seriously and are familiar with the results and applications of PER.
3. Attention to the service courses won the department an excellent reputation on campus and material support from the administration.
4. The department chair has provided strong leadership in implementing the changes.
5. The administration has recognized the growth in the numbers of majors by allowing the department to hire three new faculty members who are keys to building an in-house research program involving undergraduates.

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J. CASE STUDY: Harvard University

The Setting:

Leading research university generally ranked among the top two or three nationally. Physics Department has 40 full-time faculty members, a Director of the Physics Laboratories, a Director of the High Energy Physics Laboratory, a Head Tutor (Director of Undergraduate Studies), an Instructional Laboratory Associate in Physics and 27 Administrative and Support Staff. The department has outstanding and well-funded research programs and a distinguished graduate program.

The Physics Department graduates 50–60 majors (called concentrators) a year; 40–50% of graduates go to graduate school in physics or a closely related field. The remainder pursue a wide range of careers including medical school, law school or business school as well as immediate employment.

Twenty-five percent of concentrators are women; 5% black, 20% Asian, and 6% Latino.

What Has Been Done:

1. Concentrators are required to take a relatively small number of courses relative to other science concentrations at Harvard.

   – The concentration is flexible, and the physics department gives formal recognition to the connections between physics and other disciplines. For example, a combined physics and chemistry concentration, a program of the Physics Department, draws 10–15 students each year. There are other joint concentrations such as Physics-Mathematics, Physics-Astronomy and Physics-History of Science that are done frequently.

2. The faculty are enthusiastic about both undergraduate students and physics.

   – All faculty teach in the undergraduate program although not every year. They take pride in their teaching and continually develop new materials and courses such as the honors introductory course for very well-prepared students. Service courses and core courses to meet the science requirements of nonscience students are considered important as well as courses for majors.

   – The chair stresses the importance of excellent teaching to all new faculty. Many faculty take advantage the services offered by Harvard's Bok Center for Teaching and Learning to improve their teaching. Graduate student T.A.s take a two-day training session from the center followed by sessions of micro-teaching and video taping.

   – Many undergraduates participate in research through an independent research course that allows up to two semester courses credit for participating in independent research supervised by faculty members. The department supports a number of students to do independent research during the summer. Five to 10 undergraduates work as T.A.s helping with large undergraduate sections.

3. The department establishes a community of physics students.

   – The active SPS chapter organizes a "buddy" system that teams first-year students with upper-division concentrators, produces a booklet of advice for new concentrators, organizes lunches and picnics for students and professors, and sponsors weekly "Cool Physics" sessions where a student talks about research. SPS surveyed physics concentrators and shared results with the department. Its officers meet with the chair and head tutor to discuss issues of importance to undergraduates.

– There are many other opportunities for faculty-student interactions, both formal and informal. These activities include study nights, lunches, dinners, weekly presentations by faculty of their research, the Physics Answer Center organized by the graduate students, and undergraduate participation in an annual “puppet show” where graduate students “roast” the faculty members. The physics undergraduates consider themselves active members of a lively physics community.

4. The department insures that all students receive careful advising.

   – The head tutor meets individually with all students choosing to enter the concentration to discuss their interests and course plans. She then assigns each student to a member of the faculty who will act as mentor/academic advisor throughout the student’s career in the department. The head tutor also remains available for any student needing advice. She checks to see that students complete requirements and are aware of other opportunities.

Indicators of Success:

1. Harvard is one of the leading producers of physics graduates at the bachelor level in the nation.
2. Undergraduates clearly take pride in belonging to a lively, close-knit community. SPS events draw both concentrators and friends of concentrators so that mailings go to 500 students.
3. Three physics faculty have recently won Harvard’s Levinson Teaching Prize.

Keys to Making the Changes:

1. The department has a good sense of the capabilities and aspirations of Harvard students and designs a challenging program to meet their expectations. At the same time, the department recognizes that students often have wide-ranging academic interests and career goals and has a concentrators program that is unusually flexible in course requirements with a number of varied options.
2. The department fosters excellence in undergraduate teaching by means of direct comments from the chair, the availability of services of the Bok Center for Teaching and Learning, and department-wide discussions of the undergraduate program at faculty meetings.
3. The department encourages and supports a number of informal interactions among faculty and undergraduates. The culture of the department is that of a lively intellectual community of which undergraduates are important members.
4. The department chairs have played a leadership role in re-enforcing the importance of good undergraduate teaching and keeping a focus on evaluating and rethinking the undergraduate program.
5. The department supports the activities of a lively SPS chapter and uses it to encourage undergraduate input into its undergraduate program.

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K. CASE STUDY: University of Illinois

The Setting:

A major research department that brings in around $17 million annually in external research support and is nationally ranked in several subfields. Sixty-four tenure-line faculty; 38 affiliate faculty; 59 postdocs.

There were 257 undergraduate majors and 238 Ph.D. students in the fall of 2001. Seventy percent of bachelors-level graduates attend graduate school in some field of physics. The department graduates 25–30 majors per year.

Total undergraduate course enrollment is approximately 2,500 students per semester.

What Has Been Done:

1. A major revision of the introductory sequence in both algebra and calculus-based physics featuring:
   - New labs based on "predict, observe, explain" model
   - Two-hour discussion sections during which T.A.s act as coaches to students working in groups on solving problems
   - Lectures based on power point slides using the department's traditional strength in demonstrations
   - Homework done on the web now includes on-line quizzes and new interactive examples to teach students problem-solving skills
   - In the calculus-based sequence, the former sequence of three 4-credit-hour courses replaced by a more flexible format of two 4-credit-hour courses (mechanics and E&M) plus two 2-credit-hour courses (thermal physics, and waves and quantum mechanics)
2. Development of an infrastructure to support and sustain the revised courses.
   - Introductory courses are taught by teams of faculty who fill roles as lecturers to large (300 student) sections, laboratory coordinator and discussion section coordinator. This has changed the intro courses from isolated, draining faculty assignments into desirable assignments where new faculty can be mentored by experienced team members. Common exams are developed by the entire team.
   - An Associate Head for Undergraduate Programs has been added to the department and the undergraduate staff has been increased to two people who handle all record-keeping and the majority of student problems freeing faculty time for substantive teaching and research.
   - An intense T.A. training program has been introduced to mentor T.A.s in all aspects of teaching but particularly in the interactive methods used in the discussion sections
3. Addition of a staff person with a master's degree in chemistry to manage recruiting, the REU program, the Saturday Physics Honors Program which presents topics in physics to prospective students and the public, and to work with the departmental website. She counsels students who seek to avoid enrollment caps in engineering disciplines by declaring physics majors without any intention of studying physics.

4. A one-credit-hour called Physics Orientation taught by the department head to introduce freshmen to departmental facilities, research programs and career opportunities in physics.
5. Two new courses targeted at definite groups of students: Physics 100 prepares students with weak backgrounds for the calculus-based physics course. Physics 212 is a one-credit "companion" course to the E&M course in the introductory sequence aimed at the most able students to challenge them with extra topics such as relativity and to prepare them for upper-division physics courses.
6. A dozen or so majors participate in an active Physics Society which organizes talks and field trips. Approximately the same number man the Physics Van which presents programs at local schools and museums.
7. A new course beginning in the second semester of junior year and including a summer of research and the first semester of senior year to provide students with research and presentation skills. It is targeted at students who plan to go to graduate school.
8. An active REU program and an astrophysics program involving undergraduates in research beginning in their sophomore year.

Indicators of Success:

1. Greater satisfaction with the introductory physics sequence among client disciplines and students from these disciplines as well as physics majors.
2. Faculty enjoy teaching the introductory sequence as members of a team, and the assignment is no longer considered a detriment to research. New faculty are mentored as members of the team.
3. Enrollments have risen from 57 freshmen physics majors in 1998 to 98 freshmen in 2001. This dramatic rise is not yet reflected in graduation rates which have increased only modestly but should eventually reflect the increase in freshmen.
4. Failure rate in the calculus-based sequence for students who have completed Physics 100 has been halved.
5. Several department faculty have received major university awards for their teaching, and their efforts are recognized within the department's reward system.
6. Student ratings of T.A.s have increased steadily from the beginning of the reform effort. In 1997, 20% of the physics T.A.s were ranked as excellent by their students. In 2001, 75% of the physics T.A.s were ranked as excellent by their students.
7. An active program in Physics Education Research has received external funding and begun to attract graduate students. The work of this research group supports changes in other physics courses.

Keys to Making the Changes:

1. The departmental leadership and most faculty believe that undergraduate education is important to the department. While recognizing its importance, they are pragmatists in recognizing the faculty, particularly junior faculty, must place priority on establishing their research. Thus they have attempted to make changes that allow faculty to do excellent undergraduate teaching without demanding an exorbitant time commitment.

2. The department is located in the College of Engineering which shares its emphasis on the importance of excellent undergraduate education. Excellent teaching is important in promotion and tenure decisions at both the college and departmental levels.
3. Majors are counted at the college rather than the departmental level so the department is not under immediate pressure to increase the numbers of majors. Reforms were implemented only after a year of discussion among faculty and a lengthy process of building consensus.
4. The department has built on a tradition of collegiality as it goes about making changes. The revised courses belong to the team teaching them and to the department as a whole rather than to any single faculty member.
5. The changes in the department have used skilled professional staff to undertake many important tasks such as recruiting which frees faculty members to do the research critical for their success.
6. Because it is large, the department can find internal resources to support instructional improvements by such measures as providing release time to faculty or reallocating staff slots.
7. The improvement of the undergraduate program is a priority for the current department head and his predecessor. They have worked to shift resources to support changes and to establish rewards for faculty who are excellent teachers. The revision of the introductory sequence required substantial released time for faculty and the hiring of support staff.

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L. CASE STUDY: North Carolina State University

The Setting:

Large research-oriented department with close ties to the School of Engineering. The Department of Physics split from the Nuclear Engineering Department in 1963 and about 60% of the department's research effort is applied. There are 36 tenure-line faculty members, 10 research faculty and visiting lecturers, 15 other Ph.D.s, and 15 staff members.

There were 120 undergraduate majors and 85 graduate students in the spring of 2001. Between 1998 and 2001, about one-fourth of physics bachelors graduates enter graduate school in physics; one-fifth continue their education in another field; a fourth find jobs in technical fields; and the remainder pursue other paths. The department graduates about 20 majors per year.

The total undergraduate course enrollment is approximately 2,550 students per semester.

Students are admitted to departments rather than to the university. In 1996, the College of Physical and Mathematical Sciences where physics resides substantially raised admission standards above those of the School of Engineering to stop the influx of students seeking to enter engineering through science departments. College enrollments immediately dropped by one-third, but have since recovered.

What Has Been Done:

1. After in-depth discussion, the department decided to maintain a rigorous traditional physics major. The department is pleased with the success of its traditional B.S. graduates, so has chosen to address its strategic goal of a 50% increase in graduates (to about 30/yr) by developing a new B.A. track, rather than by modifying the B.S. The department gives very high priority to recruiting extremely able students.
2. The department works extremely effectively to mentor undergraduate majors and build community within the department.
   – Majors enter a special section of the introductory calculus-based course with special laboratories and a unique curriculum.
   – New majors are welcomed to the department with a reception early in the academic year and encouraged to join a very active SPS chapter which meets every other week and does four to five activities per semester.
   – Instructors in the introductory course for majors assign group projects to encourage students to work together. By junior year, most physics majors work in informal study groups.
   – A small group of faculty advisors work closely with each class of majors and follows them from freshman year to graduation.
   – There is an undergraduate study room and generous resources for worthwhile projects or that essential supply, pizza.
   – Undergraduates are hired early to work for the department, for example setting up demonstrations or as tutors, in order to involve them in the life of the department.
3. All majors are encouraged to participate in research. The department has a long-standing REU program and presents cash awards for outstanding student research. The majority of undergraduates are mentored by a few faculty members whose research

programs divide into small projects, but there is broad participation by all faculty in mentoring undergraduate research.

4. The senior laboratory has been revised to focus on individual projects that the student must design, review the literature, write up and present to the class.
5. The undergraduate director of the department works closely with the director of admissions of the College of Physical and Mathematical Sciences to attract able students.
   – The undergraduate director calls prospective students, meets with them and their families, and encourages students who wish to transfer into physics majors.
   – The introductory course has an honors section for able engineering students from which the department actively recruits physics majors.
   – The department recruits high school students through mentoring programs involving lab experiences and visits to schools. Other outreach to K–12 students and the public is handled through Science House.
   – Students who do exceptionally well in engineering physics sections receive a letter from their instructor congratulating them on their performance and suggesting that they consider a physics minor. A few such students wind up adding or changing to physics.
6. Students are encouraged to carry double majors, and the department has worked out arrangements with engineering departments to facilitate this by such means as substituting engineering courses for physics requirements, and vice versa.
7. Four years ago, the department established a B.A. degree with reduced requirements in traditional physics to facilitate double majors and attract more students. No new courses were developed to support it. As of May 2001, 17 students have graduated from the program (out of a total of 52 since the first B.A.s were awarded). They have been competitive in the job market, a pleasant surprise to the department head.
8. The department encourages recent graduates who have entered industry to interact with their current students through a banquet for alumni and students. They plan other activities to raise students' awareness of industrial careers that will make use of their large number of successful graduates.
9. The structure of the introductory courses is designed to free faculty for research. The 15 sections of introductory calculus-based physics are coordinated by a single faculty member who makes up the syllabus indicating what topics are to be covered each day, constructs the exams, and places homework assignments on WebAssign which was developed at the university.
10. Three sections of the intro course are offered in the interactive Scale-Up format.
11. There is a thriving and active Physics Tutorial Center.
12. An extensive system of lecture demonstrations was set up by a member of PIRA and is overseen by a staff of students.

Indicators of Success:

1. Very high morale among both faculty and physics majors. They are extremely proud of one another. There is no problem making upper division courses meet enrollment targets, and they expect to replace retiring faculty members.
2. Most faculty and students know one another by name. They form a close-knit community and celebrate others' achievements.
3. Enrollments in physics have returned to their pre-1996 levels despite higher admissions standards.
4. Half the students carry double majors with math in first place and engineering in second.
5. The department has produced three finalists for the Apker Award and one winner.
6. The department has a thriving Physics Education Research Group that has developed the Scale-Up model for introducing interactive instruction to large sections of introductory physics. The group attracts very able graduate students and substantial external funding.

Keys to Making the Changes:

1. The driving force for making changes in the undergraduate physics program is the nearly universal conviction of the faculty that it is important to do an excellent job in preparing undergraduate physics major, not pressure from outside the department.
2. The faculty as a whole participated in the discussions that led to the strategy of concentrating physics on the most able students. There is nearly complete consensus within the department that physics majors are "found" and "authorized" to study physics.
3. The department has a tradition of working collaboratively with engineering departments that has facilitated the development of double majors and other strategies linking departments to the benefit of students.
4. The department faculty work collegially among themselves and with students. The warmth of the faculty for students is a terrifically appealing feature of this department.
5. Department chairs have provided strong leadership in recognizing the importance of the undergraduate program and in providing resources and faculty rewards needed to do it well.

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M. CASE STUDY: North Park University

The Setting:

Small, church-related university with 2,300 students that has offered a four-year curriculum since 1958. About 275 incoming freshmen in each class. Twenty physics majors at all levels and an average of five graduating each year.

About 50% of physics majors continue their education after graduation but not necessarily in physics, 14% enter K–12 teaching, and the remainder find employment in a wide variety of positions.

The Physics Department has two faculty members, no staff, and an annual budget for supplies and equipment raised this year to $10,000 from $2,500. Their space is limited to one large lecture/lab area, a laboratory and two offices.

What Has Been Done:

1. The department chair aggressively recruits students who are interested in physics, engineering or science in general and are considering North Park University.
   – She writes (emails) all prospective students interested in physics, engineering or science describing the department and inviting them for a visit.
   – Students visiting campus and their parents visit with her in the department and receive a humorous post card as a follow up.
   – The department chair teaches the introductory physics course so students begin their career already acquainted with one of their professors.
2. The department creates a “home” for physics majors within the department.
   – The lecture/lab room is equipped with a combination lock so physics majors have access 24 hours a day. The room is equipped with computers and has become both an academic and social center for the majors. They remain in the room during the introductory physics course so all majors know all other majors.
   – The departmental atmosphere is kept informal. Faculty and students are on a first name basis with students visiting faculty homes and all members of the department familiar with one another’s personal concerns and triumphs.
3. The Physics Department has a very broad definition of success for its graduates. They consider physics an excellent basis for almost any career and teach accordingly.
   – Students are encouraged to carry double majors not only in math and engineering but in areas such as philosophy and languages.
   – Faculty team teach courses with faculty from other disciplines and work closely with colleagues from other academic disciplines.
4. The two faculty offer an academically solid physics major that provides minimum essential preparation for those students who wish to enter graduate school.
   – Majors take a special one-credit hour course along with the introductory sequence to improve their math and computer skills and prepare them for upper-division courses.
   – Introductory labs are taught without formal instructions so students learn to design experiments, prepare proposals, and present their results as 10-minute papers. Group work is introduced in the lecture and homework is submitted via WebAssign.

– Upper-division courses are tailored to the needs of individual students and feature projects, both individual and group.

5. Students are encouraged to participate in REUs and internships off campus in the summers because there is little opportunity for research experiences on campus. The faculty use a network of alums and professional acquaintances to help place students. They collaborate with colleagues at other larger institutions.

Indicators of Success:

1. This very small department consistently graduates an average of more than five majors each year.
2. Morale is very high within the department, and the department is widely respected on campus.
3. The recruiting effort's effectiveness is demonstrated by a decline in majors following the year when the chair was on sabbatical.
4. Students succeed in graduate programs as well as in a variety of other careers.
5. One of the faculty members is very well known and active in the larger physics education community. Both faculty members are intellectually active in their own research areas and successful in obtaining outside funding (not a tradition at North Park).

Keys to Making the Changes:

1. Collegiality and shared vision are absolutely essential if a small department is to build and maintain a strong undergraduate physics program.
2. Change required support from the chair of the Mathematics and Science Division and faculty from other disciplines.
3. Faculty success in obtaining outside funding enabled the purchase of high-quality laboratory and computer equipment and some employment of students on projects.
4. Networking and collaboration with other departments helps the North Park faculty stay intellectually alive.
5. Both faculty members remain intellectually active and excited about physics, teaching physics and their students.

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N. CASE STUDY: Oregon State University

The Setting:

A state-assisted university with about 18,000 students of whom 14,500 are undergraduates. The university has traditional strength in the sciences, engineering, oceanography, forestry, and agriculture. It has been growing steadily in spite of continuing state budget crises.

The Department of Physics has 15 tenure-line faculty and one or two full-time adjunct faculty members recruited to teach the large introductory courses. It has one full-time technician, a second technician shared with chemistry, and four office staff who also administer departmental grants. The department currently enrolls about 35 Ph.D. candidates and attracts about $1.5 million annually in research funding including several large grants aimed at undergraduate education, and it is in the process of developing a professional masters program with funding from Sloan.

The department offers B.S. degrees in Physics and Engineering Physics and initiated a new B.S. degree in Computational Physics this year. The department currently enrolls about 110 undergraduate majors in all years.

The Department of Physics receives an unusually high percentage of its majors as transfer students from two-year colleges or other institutions. About a quarter of undergraduate majors transfer in for the sophomore year and another quarter enter before their junior year. A quarter declare physics majors as entering freshmen and another quarter declare majors in engineering physics although many of them eventually become physics majors.

What Has Been Done:

1. In 1996, the department undertook a major revision of its upper-division physics curriculum to allow flexibility in scheduling so that engineering physics majors could participate in an internship and to help students make the transition in difficulty from lower-division physics courses to upper-division courses.
   – The Paradigms Project reorganized the junior-level curriculum into nine 3-week-long paradigms courses, each of which focuses on a class of physics problem that appears in more than one subdiscipline of physics, oscillations or static vector fields for example. In addition, the Paradigms courses introduce new, research-based pedagogies that encourage students to work and study in groups and to take responsibility for their own learning.
   – In their senior years, students take capstone courses in traditional subdisciplines of physics. Because students have been exposed to some material in the paradigms courses, the capstone courses can cover material more rapidly. They are taught more traditionally than the paradigms to prepare students for graduate school experiences.
2. The department has built on its traditional strength in computational physics to introduce a new undergraduate major in the field. The program has received external funding from NSF and DOE. The first students are enrolling now.
3. The Department of Physics was recently selected as one of six primary sites for the Physics Teacher Education Coalition. This program will introduce two new majors appropriate to preservice teachers as well as promote revision in the calculus-based introductory course.

4. The department recruits physics majors not only by supporting the recruiting activities of the College of Sciences, by responding to inquiries from prospective students, and by maintaining collegial relations with local high school teachers and TYC faculty, but also by actively recruiting talented students in the modern physics course which is taken by students from several engineering disciplines.
5. Students form a community, particularly after the paradigms sequence during which they form close-knit study groups. They have access to a study room with all amenities including tables with white board tops on which they can write, access to the paradigms classroom and to a computer room. The department has Sigma Pi Sigma and SPS chapters.
6. Students are assigned to a faculty advisor as soon as they declare a physics major. The Director of Undergraduate Programs oversees advising and is known as the person to come to for answers to scheduling and other problems. Faculty are accessible to students, particularly during the paradigms courses when they work intensely with the students in their courses.
7. All physics majors are required to complete a research project. Most faculty advise an undergraduate or two on research projects although some of them work with advisors in other science departments or meet the requirement through participation in REU programs.
8. Revisions introduced into the algebra-based include lectures with an electronic response system, concept-based laboratories, and the introduction of tutorials in recitation sections.

Indicators of Success:

1. The number of physics graduates has increased and continues to increase. In 1999, 12 majors graduated; in 2000, 15 majors graduated, and in 2001, 22 majors graduated.
2. Since the introduction of the Paradigms and Capstone courses, GRE scores have held steady, even though more and weaker students take the exam. In addition, students have formed a much closer community and rate the paradigms courses as the best part of their undergraduate physics experience.
3. Nearly all faculty members are actively involved in one of the undergraduate projects.
4. The administration recognizes and respects the work of the Department of Physics.
5. Faculty from client disciplines respect the work of the physics department in education and, even when there are problems, express confidence that the department will fix them.

Keys to Making the Changes:

1. Major revisions are supported by a strong faculty consensus, and all faculty take responsibility for the excellence of the undergraduate program in physics.
2. Department chairs have provided strong leadership in recognizing the importance of the undergraduate program and building faculty support for revisions.
3. External funding, particularly from the National Science Foundation, has played a key role in making major curricular revisions possible during a time of contracting state budgets.

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O. CASE STUDY: Reed College

The Setting:

An independent and highly selective private liberal arts college enrolling about 1,400 students. The college offers 22 department-based majors and 12 interdisciplinary majors. Students must complete a core curriculum in arts and sciences. All students must pass a qualifying exam in the junior year, and all must complete and defend a senior thesis.

Reed maintains a casual atmosphere between faculty and students; students and faculty are all on a first-name basis. Grades are de-emphasized; professors assign grades in each course, but students do not routinely receive a grade report.

The physics department consists of six tenure-track faculty and one adjunct. Support staff include a secretary, a machinist, and an electronics technician.

Reed awards an average of 19 physics degrees each year, which represents about 7% of the total number of baccalaureate degrees awarded by the college and about 30% of the math and science degrees. About 20% of the physics degrees are awarded to women. Typically 50% of the graduates enter graduate school in physics or related areas. Very few become high-school teachers.

What Has Been Done:

1. The college offers a traditional undergraduate curriculum leading to the B.S., but students can also earn degrees in one of three alternate tracks: a joint chemistry/physics program, a joint mathematics/physics program, and a 3/2 engineering program (in which the final two years of engineering work is taken at Columbia or Cal Tech). About one-third of the degrees are earned in the alternate tracks.
2. Two years of introductory physics are offered. The second-year course, which enrolls about 30 students (mostly physics majors), is taught in the lecture/laboratory/conference mode. The laboratory has been modified to emphasize acquiring electronics skills and learning to solve problems using Mathematica. Individual faculty-student conferences are used to critique the lab work.
3. A major effort has gone into developing the junior-year laboratory experience. The first semester emphasizes electronics, and the second semester is based around student projects using sophisticated apparatus to perform contemporary experiments. The course makes extensive use of LabVIEW, which permits experiments to be computer interfaced and controlled. These course revisions were supported by grants from the NSF and the Murdock Trust.
4. The department has recently received a $500,000 Keck Foundation grant (matched by the college) to undertake a revision of the instructional laboratory program, which will include developing inquiry-based labs for the first-year course and upgrades of the equipment for the second-year course and the advanced lab. The grant will fund a lab manager to support the course improvements; the college will continue to support that position when the grant is concluded.
5. The senior thesis is a unifying element that forges bonds among the students as well as between students and faculty.

Indicators of Success:

1. Reed ranks among the top small colleges in the United States in number of physics degrees awarded and exceeds 80% of the Ph.D.-granting institutions. The number of physics graduates has remained steady or increased while the national total has declined.
2. Retention of majors is very high.
3. There is a cohesive, supportive, and collegial attitude that pervades the department. Students are mutually supportive and do not compete with one another for grades
4. The department has received substantial extramural funding for course and curriculum development.
5. The department is well respected on campus and has the strong support of the college administration.

Keys to Making the Changes:

1. The faculty is committed to curricular reform.
2. The department has deliberately chosen to emphasize undergraduate education over funded research as a measure of faculty accomplishment, and the college administration has supported that decision (even though other science departments at Reed take a more traditional view of the faculty reward system).
3. External funding and college matching funds have enabled laboratory course improvements.
4. The conferences in the second-year course serve to develop the close bond that forms between faculty and students.
5. Students are invited to serve as undergraduate T.A.s as early as the sophomore year. This attracts students into the major and builds the cohesive spirit in the department.
6. The senior thesis is a unifying element and a capstone experience for the students.
7. The department maintains an active seminar program that involves undergraduates.
8. The college and the department set high standards and then focus their resources to assist students in meeting those standards.

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P. CASE STUDY: Rutgers University

The Setting:

A public, land-grant, Research 1 institution with about 26,000 undergraduate students. The university includes several colleges, in particular Rutgers College which awards most of the undergraduate physics degrees, Douglas College, a woman's college, and a School of Engineering.

The Department of Physics and Astronomy consists of 65 faculty members, of whom 20% are astronomers, four are research professors, and several have joint appointments with various research centers. There are five full-time instructional support staff members.

Women represent about 20% of majors, Asian 13%, Hispanics 3% and 5% are of mixed race. 20% of majors received a 4 or a 5 on one of the Physics AP tests, and a quarter of majors are transfer students, often from New Jersey community or county colleges. Twenty to 25% of students go to graduate school usually in physics or astrophysics, one to two become K–12 teachers, 10% go to professional school, and the remainder enter the workforce, commonly in technical jobs.

What Has Been Done:

1. Undergraduate advising has been centralized with one capable and caring advisor working with all 150 undergraduate majors.
   – Advice is consistent and professional and students feel that the advisor and hence the department cares for their success. He maintains an open door policy for students.
2. The department offers four options for a physics major.
   – The Professional Option in Physics or Astrophysics (B.S.) leads to a B.S. and prepares students for graduate school. The General Option (B.A.) is designed for students who are interested in physics but do not intend to become professional physicists. The Dual Degree option allows students to obtain an engineering degree and a degree in physics.

3 The department offers a variety of introductory courses in physics that respond to the diverse academic preparation of entering students.
   – A three-semester honors sequence targets well-prepared students; a two-semester course serves students in the General Option and biological science students; and a four-semester sequence is taken by engineering majors and physics majors not enrolled in the honors sequence. "Extended" versions of the first two semesters of the four-semester sequence and the two-semester sequence are offered for one extra credit per semester and target students who are less well-prepared. The "extended" courses use cooperative workshops and integrated labs to provide extra time for students to absorb physics. In addition, there is an experimental algebra-trig course in place at Douglass College featuring group workshops and an integrated laboratory.
   – The department created a Physics Learning Center which was generalized and now operates as the Math and Science Learning Center to provide review sessions, physics videotapes, copies of old exams, and a congenial place for students to meet and study.

4. The department has revised introductory laboratories to emphasize more of a discovery experience and to make effective use of computers. The primary physics lecture hall has been fitted with a state-of-the-art audio visual system and a personal response system, a staff member works to develop and prepare demonstrations, and half a dozen courses use WebAssign.
5. Students are encouraged to participate in research through taking jobs in faculty labs or through participation in the department's Honors Program which requires a senior thesis. Honors students' work is showcased in a variety of department forums.
6. The active SPS chapter runs a free, informal tutoring service for students in the introductory courses. Students have the use of a room in the Math and Science Learning Center for two nights each week.
7. The department has an active T.A. training program including visiting and video-taping each T.A.
8. The department participates in university recruiting activities such as the Open House for high school students as well as providing personal tours for interested students and their parents. In addition, several faculty members are involved in projects that introduce students and teachers to new developments in particle physics and astrophysics as well as in demonstration shows for school groups and the general public.

Indicators of Success:

1. The department currently graduates about 40 students per year which represents a doubling in the number of majors since 1980.
2. Approximately 0.6% of the undergraduate degrees awarded by Rutgers are in physics, more than double the national average for physics departments.
3. Students speak warmly of the sense of community in the department and faculty efforts to involve them in research. They feel the department compares very favorably to other science departments at Rutgers.
4. Students in "extended" introductory courses obtain exam scores that duplicate those of students in the regular sequence.

Keys to Making the Changes:

1. The department appointed an Associate Chair who serves as Undergraduate Program Director and takes full responsibility for all aspects of the program and serves as advisor to all undergraduates.
2. The department has aggressively sought and obtained university and NSF funding to support improvements in instructional facilities and equipment.
3. A generous donation allows the department to offer seven full-tuition scholarships for majors each year as well as two summer research internships.

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Q. CASE STUDY: State University of New York at Geneseo

The Setting:

A highly selective public four-year college with a total student population of about 5,100 students. Geneseo prides itself on being the best liberal arts college in the SUNY system, and in addition has Schools of Business, Education and Performing Arts as well as several masters programs. The college is increasingly emphasizing research, publication, and creative accomplishments.

The Department of Physics and Astronomy has eight tenure-track faculty members, of whom one is on research leave and has been replaced by a visiting assistant professor and a second serves as Associate Provost. Six of the tenure-track faculty members have been hired since 1993. Staff consist of a senior instructional support specialist and a full-time secretary. The department employs junior and senior physics majors as undergraduate lab instructors who work with faculty in the labs.

The department offers a B.A. degree in physics, a B.S. degree in applied physics and participates in a 3/2 engineering program. About 17% of physics graduates pursue Ph.D. programs in physics; 28% enter Ph.D. or masters programs in engineering; 13% pursue graduate or professional degrees in other areas; 14% enter the workforce; 11% complete 3/2 engineering programs, and 6% enter public school teaching.

What Has Been Done:

1. Following a tradition built at its founding in the 1960s, the department emphasizes close student-faculty interactions.

   – Faculty maintain an open-door policy for students. The department promotes an active physics club and an annual bridge-building contest to build departmental community. Faculty hiring efforts are aimed at bringing in faculty who will maintain that tradition.

   – Undergraduate majors get keys to the building and a computer area, and they use instructional labs in the late afternoon and evening. Faculty offices are close to the student areas, and students find they can talk to faculty about anything, including courses faculty are not currently teaching.

   – The department keeps photographs of all majors and faculty members on bulletin boards near the department office. They maintain a map showing the location of previous graduates. The department uses its weekly colloquium for a mix of research talks, talks about careers and student activities such as the bridge building contest or Physics Bowl.

2. Students who enter Geneseo with an expressed interest in physics are encouraged to enroll in a one-credit First-Year Physics Experience course that allows students to meet one another, upper classmen and the physics faculty.
3. The department recruits students when they are first admitted to Geneseo. They contact all students who express an interest in physics and astronomy as well as those whose academic preparation suggests they can succeed in physics. They actively recruit physics majors in the introductory course. About 40 students a year express interest in the 3/2 engineering program, and many of them convert to physics majors.
4. The B.A. in physics has minimum requirements allowing flexibility. Most students take more physics than the minimum requirement, and the B.S. in applied physics requires more courses including electronics and computer science.

5. Well over half the physics majors have a summer research experience either at Geneseo or in an off-campus research program.
   – Six of the current faculty members have externally funded research projects. The department uses its two MeV Van de Graff accelerator to calibrate detectors for laser fusion efforts at the University of Rochester and Lawrence Livermore National Laboratory.
6. The department works to extend the feeling of community to students in service courses.
   – Faculty take pictures of all students during the first week of classes and learn all names within a week or so.

Indicators of Success:

1. In the last nine years, the department has graduated an average of 17 physics majors per year of whom 22% were women and 4%, minorities. There are currently 76 declared majors in all four years.
2. From their freshman years on, students express a strong sense of belonging to the physics department. They use the word "family" to describe their experience. They are aware of anecdotes about past students and events.
3. The department has the reputation of being a challenging but friendly department that provides a high quality academic program.
4. The administration holds the department in high regard because of their devotion to teaching and time spent involving students in research.

Keys to Making the Changes:

1. The physics department has a strong and clear sense of its mission that is shared by all faculty members within the department.
2. Communication among faculty members has high priority. Physics faculty members have lunch every week which allows the faculty members to communicate informally. In addition, they have a formal faculty meeting once a week. Generally important decisions require much discussion and are resolved by consensus.
3. The department has had strong leadership from chairs who have been able to form a consensus on the mission and direction of the department.
4. The entire department has worked to recruit faculty members who will support the department's mission and to keep them. The chair chats with them informally but regularly as they become part of the physics "family."
5. The college also works to integrate junior faculty into the larger community through putting them on committees in their second years and through a Teaching/Learning Center.
6. The administration provides strong institutional support for the mission of the department which fits well into the overall mission of Geneseo.

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R. CASE STUDY: University of Virginia

The Setting:

Moderate-size state-supported research university with 12,500 undergraduates and 6,000 graduate and professional students. The Physics Department has active research in the major fields of physics, particularly at Thomas Jefferson National Accelerator Laboratory, and $5 million in external funding each year.

The department has 34 tenure-line faculty members, five research faculty, a general faculty members who is Director of Laboratories, a visiting professor, a lecturer and 26 research associates and scientists. There are 25 supporting staff and 72 graduate students.

On average, 32 physics majors graduate each year. Twenty-five percent were women and 30% were double majors. Twenty-five percent went to graduate school in physics and another 25% continued their studies in another field or in professional school. Two-thousand majors and non-majors enroll in 25 undergraduate courses each semester.

What Has Been Done:

1. In 1995, a new and more flexible B.A. degree designed for students who do not plan to attend graduate school went into effect with reduced requirements in math and upper division physics.
   – Two new courses, “Widely Applied Physics,” treat principles of physics from the perspective of modern applications and form a key component of the new degree.
2. In the period 1991 to 1993, the department instituted two new courses designed for liberal arts students. The two-semester “How Things Work” and the one-semester “Galileo and Einstein” courses have attracted large numbers of students to the department helping increase the numbers of student credit hours generated each semester. These courses, as well as all of the introductory courses for majors and non-majors, make extensive use of lecture demonstrations provided by a well-equipped Lecture Demonstration Facility, whose staff of two full-time and a part-time member provide more than 2,000 individual experimental demos each semester.
3. The introductory and upper-level laboratory courses for physics majors have been revitalized and upgraded using nearly $200,000 in internal and external funding. Computers are used for data acquisition and analysis at all levels, and techniques learned in the introductory laboratory are coordinated with practices in the upper-level laboratory courses. The labs incorporate new experiments in modern physics. Most undergraduate physics majors work on research in faculty labs where they are able to make use of techniques learned in the new laboratory courses and to carry out independent study projects.
4. When the number of credit hours required for engineers was reduced from 12 to eight, a joint committee of engineering and physics faculty worked to design new studio-style workshops to replace conventional laboratories and recitation sections.
   – The new workshops are carried out in a physics lab with 24 students per section, working in cooperative groups of three on labs and problem solving. The workshops incorporate the methods of Real Time Physics and use WebAssign. Lectures in the course use interactive lecture demonstrations and WebAssign for problem assignments. A popular resource for this course is a room staffed by a teaching assistant during afternoons and early evenings where individuals and groups of students come to ask questions and receive tutorial assistance.

5. The department created a Master of Arts in Physics Education program designed for high school and middle school teachers who do not have an undergraduate degree in physics. The Physics Department offers 14 courses for the professional development of K–12 teachers to improve their competency in physics and to assist them in obtaining endorsement or recertification. The department offers a course based on *Powerful Ideas for Physical Science* for pre-service elementary and middle school teachers.
6. The process of revitalizing the department is continuing. Current projects include three new courses in computational physics and three new courses in optics to support new optional concentrations in computational physics and optics.

Indicators of Success:

1. Since 1995, the department has graduated an average of 32 physics majors per year. Before 1995, they averaged 20 majors per year.
2. The B.A. has attracted new majors to the department without producing a significant decline in the number of majors in the traditional and rigorous B.S. program.
3. The two new liberal arts courses attract around 900 students each year. "How Things Work" has generated a textbook and national attention and imitation.
4. About two-thirds of faculty are actively involved in undergraduate teaching at the present time.
5. Morale among physics majors is very good, and majors are pleased with their opportunities for informal interaction with the faculty.
6. The Physics Department is viewed very positively by most of the students taking courses in the department, and approximately a third of all University of Virginia students take at least one course in physics before graduating.

Keys to Making the Changes:

1. The department as a whole is very involved with undergraduate education and feels that undergraduate education is an important part of its members' professional responsibilities. Ideas for change come from the faculty and are channeled through an active undergraduate committee.
2. The college administration encourages changes that increase the numbers of majors and the enrollments in service courses. Administrators have both put pressure on the department to change and supported efforts to do so.
3. The Department of Physics has an excellent working relationship with the College of Engineering allowing the formation of joint committees when problems arise in the service courses. The department also maintains good relations with the Department of Astronomy. About five majors per year graduate with a B.A. in Astronomy/Physics.
4. The environment in the department is dynamic and open to change.
5. The department is acutely aware of its role in educating future K–12 teachers and providing inservice activities.
6. The department has succeeded in attracting nearly half a million dollars from internal and external sources to support revision of its courses.

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S. CASE STUDY: Whitman College

The Setting:

A private liberal arts college with an undergraduate enrollment of 1,300 students located in the southeast corner of Washington State. An excellent regional college with a faculty strongly committed to teaching and strongly coupled to their students.

The Physics Department has four tenure-line faculty members, one of whom currently teaches half time in the general studies program. The department is authorized to hire a biophysicist but has been unable to fill the slot so that the position is currently filled by a visitor with another specialty. Three of the four tenure-line faculty have been hired since 1990.

The number of majors (10 graduates per year) has remained nearly constant despite the turnover in faculty. About one-third of the students are women. Fifty to sixty percent of graduates attend graduate school and 10–20% enter high school teaching.

What Has Been Done:

1. The faculty cares deeply about students, and the students know and appreciate this concern. Doors are open, and faculty always make time for students with questions about any aspect of physics. Small sections in the introductory physics sequence allow physics majors to become well acquainted with faculty members as freshmen.
2. The department has established 3/2 programs with engineering schools at Washington University at St. Louis, Columbia University, and Cal Tech under which students obtain a B.A. from Whitman and a B.S. from the engineering program. These programs attract majors to Whitman, and many of them elect to remain at Whitman for four years and graduate as physics majors.
3. The department participates in a program of combined majors which allows the physics department to benefit from some of the unique strengths of Whitman including departments of astronomy and geology.

   – The Physics Department has decided that the flexibility inherent in the combined majors compensates for less depth in physics. The departments from which a combined major graduates each receive half credit for the major. Majors at Whitman are sized so that they require about one-third of the credit hours needed to graduate. General studies courses require another third, and the remaining third provides students options to tailor their academic programs to their individual interests.
4. A grant from the Howard Hughes Medical Institute has enabled revision of the introductory physics sequence and provided support for a tenure-line faculty member in biophysics.

   – The introductory sequence consists of two semester-long courses, taught in classes no larger than 25 students with integrated laboratories. The courses stress depth and conceptual understanding rather than encyclopedic coverage. There are usually four sections of each of the introductory courses and they are taken by chemistry, physics, geology and biochemistry majors. However, scheduling sections geared to special student interests has proven difficult.

   – The introductory labs stress measurement and analysis, and the sophomore labs can allow students to design experiments or extend existing ones in order to equip them with skills needed for research.

5. The department has created a one-credit course which meets at lunchtime to hear outside speakers talk about what scientists and engineers actually do. Lunch is provided for students who are not on the meal plan.
6. Faculty are now expected to be active in research, and student participation in that research is encouraged. On average, six students per year spend the summer working in faculty research labs.

Indicators of Success:

1. The Physics Department graduates 10 majors per year, a number in which combined majors like Physics-Mathematics and Physics-Astronomy are counted as 0.5.
2. Several Whitman physics graduates have gone on to extremely distinguished careers in physics.
3. Physics majors appreciate the attention they receive from faculty members and love the introductory course sequence.
4. Students taking the MCAT and who have gone through the introductory physics sequence average at the 80th percentile on the part of the exam that includes both physics and chemistry.
5. Faculty are successful in involving students in scholarly projects and training them for careers in graduate school as well as to directly enter the workplace.

Keys to Making the Changes:

1. The new, younger faculty recently hired have brought enthusiasm and energy to the department's programs in teaching and research.
2. The college provides a program of merit scholarships that help to attract talented students to the physics department among others. Over the last decade, the college has attracted increasingly talented and well-prepared students.
3. Whitman offers a full year of sabbatical leave after four years of full-time teaching.
4. Collaboration with the biology department has provided leadership in seeking the funds that have allowed the reform of the introductory course sequence.

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T. CASE STUDY: The University of Wisconsin–La Crosse

The Setting:

Comprehensive, state-supported university with a total enrollment of 9,200 students of whom 8,500 are undergraduates. Capped admission has made academic preparation of students, largely from Wisconsin and Minnesota, second highest among institutions in the University of Wisconsin system. La Crosse is the center of a metropolitan area of 100,000 on the border of Wisconsin and Minnesota located 140 miles from Madison and 160 miles from Minneapolis.

The Department of Physics has seven tenure-line faculty, including an astronomer who is planetarium director, and two part-time faculty, a three-fourths-time departmental secretary, and a full-time electronics technician.

The department graduates about 15 majors per year. About half graduate from La Crosse after the first year in engineering school on a 3/2 program. The majority of the others go to graduate school (most frequently in optics because of the department's research interests) and the others enter the workplace.

What Has Been Done:

1. The undergraduate physics curriculum has been completely overhauled.
   – The department has 3/2 programs with the University of Wisconsin campuses at Madison, Milwaukee, and Platteville and with the University of Minnesota. Admission for students completing the required three-year curriculum at La Crosse with a high enough grade point average is automatic.
   – The upper-division curriculum introduces specialization early so students graduate in physics or in physics with emphasis in optics, computational physics, astronomy, biomedicine, or business.
   – Students enter the major from the algebra-based introductory sequence as well as the calculus-based sequence. Their math skills even out by junior year, and the system allows all potential majors to immediately begin course work in physics and opens a much larger pool of introductory physics students to the department's recruiting efforts.
   – All laboratories have been reworked and equipped with computers and other modern equipment. Equipment from the sophomore level up is very modern and has the feel of a research lab.
2. All majors are required to participate in research or some appropriate capstone experience such as student teaching and receive course credit for doing so. The college supports this undergraduate research initiative with student research grants, travel grants for students and summer fellowships.
   – Faculty actively recruit students to research projects beginning with their arrival on campus. Many students publish and make presentations at national and regional meetings.
   – Course loads are figured on the basis of contact hours so faculty receive load credit for working with undergraduate research. They are the only department in the university to do this.

3. All freshmen and sophomore physics majors are very strongly encouraged to enroll in a one-credit hour seminar course.

   – This course, attended by 50 plus students and all faculty, is used as a primary means to build community in the department. The department provides information on research opportunities in and out of the department and brings in speakers from industry and the area to talk about using physics as a basis for a variety of careers.

4. The Physics Department aggressively recruits students and works to retain them once they arrive in the department.

   – They target likely physics majors for personal letters, award freshman scholarships, hold open houses for prospective majors and their parents, and present a very popular laser light show for middle school students. The department considers advising a critical element of students' success and works hard to provide each student with contact with a faculty advisor from the beginning. Students cite faculty mentoring and friendship as the best thing about their experience in the department.

5. The department runs summer workshops for in-service teachers and has created a physical science course for pre-service elementary teachers using inquiry-based instruction with no lectures. The pre-service course is so successful that other colleges would like to see it offered for their students even though the department does not have the personnel to do so.

6. The department pays attention to publicizing its programs within the university and the local community.

   – The chair has good working relationships with the local press who provide him with coverage for the department's activities. The department hosts an annual Distinguished Lecture Series in Physics which brings Nobel laureates to campus for the usual lectures in addition to a major banquet for local community and industrial leaders.

7. The faculty, particularly the chair, work to build community within the department.

   – Faculty members' assignments reflect their unique strengths. Junior faculty are mentored by senior faculty towards success in achieving tenure. Hires have been made carefully to strengthen the department and increase its morale.

Indicators of Success:

1. The department graduates 15 majors per year and this number continues to grow. In 1990, the department graduated about one major every other year.
2. The department's efforts are respected and supported by all levels of administration.
3. Two faculty members have won teaching awards in the last few years.
4. Faculty and students are actively publishing and presenting papers at meetings. Many faculty papers have student co-authors.
5. Students leave the program positioned for success in graduate programs and in engineering schools.
6. The department works as a team with a shared sense of mission and a real respect for one another's contributions to the work of the department.

Keys to Making the Changes:

1. The Physics Department has enjoyed sustained administrative support. Revitalization of the department began when the dean brought in an outside chair and another experienced faculty member. The administration invested resources to attract good people and to provide them with the tools they need to make effective changes.
2. The department chair provides very skillful personal leadership to the department. He leads by example, works to build consensus within the department, and enjoys great respect from university and college administrators.
3. The department works hard to build a common sense of mission and to use limited resources and people in the most effect way possible.
4. Curricular revisions have been carefully designed to meet the needs of students and are revised in response to student feedback. The department chair assigns the very best teachers to the introductory courses.
5. The department's increased emphasis on research has not diminished its focus on excellent teaching. All faculty consistently demonstrate a genuine concern for students that is recognized by the students.
6. While working hard, the department maintains a humane atmosphere where families are considered important.
7. The efforts by the department to publicize its programs have paid off in efforts to attract resources and students.

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U. CASE STUDY: Lawrence University

The Setting:

A small nondenominational, liberal arts university with about 1,300 students, a quarter of whom are enrolled in the Conservatory of Music but may double major in other disciplines. The department has four tenure-line faculty members, a visiting assistant professor, a part-time electronics technician, and a part-time machinist.

The department graduates an average of 10 physics majors each year on a single degree program although some of them also obtain a bachelor's degree in music. Approximately 50% of the graduates pursue graduate study in physics.

What Has Been Done:

1. The department offers a fairly traditional, extremely rigorous physics major and is proud of its high standards. Faculty expect students to work very hard and treat them as junior colleagues. Faculty maintain an open-door policy for helping students and clearly view undergraduate education as their core mission.
2. The department has developed signature programs in laser and computational physics, and is developing signature programs in surface physics and nonneutral plasmas.
   – A signature program is first a teaching program but has especially well-equipped laboratories and ties to faculty research so that it generates specialty courses, promotes student/faculty interactions, increases departmental pride, and supports student projects. They also help to recruit students.
3. The department works hard to attract to Lawrence talented high school students who are already inclined to major in physics.
   – The department holds an annual weekend workshop for high school seniors with strong interest in physics. The faculty select 26–30 participants from 50 or so applicants to attend a spring workshop with all expenses, including air fare, paid by Lawrence. Each participant is hosted by a Lawrence physics major and spends a day in the signature program laboratories. Approximately 30% of the attendees matriculate.
4. The department involves students in departmental affairs as contributors to curricular discussions, as participants in interviewing candidates for positions and entertaining visitors, and as laboratory assistants and help session leaders for introductory courses.
   – The department holds twice-weekly teas, an annual picnic and an annual weekend retreat. Students have 24/7 access to a student common room, labs for student research and the Computational Laboratory.
   – There is a chapter of the SPS, a Sir Isaac Newton Society, and a Women of Physics club.
5. The faculty strongly encourage student involvement in research by recommending a capstone experience for their majors and encouraging them to spend a summer either at Lawrence working with a faculty member or in a REU program elsewhere.
6. The department has developed several courses to introduce nonmajors to physics, some of which have laboratory components and some of which are oversubscribed.

7. The department currently offers an optional course in Computational Tools in Physics, but students generally lack time to participate in this course. The department is currently changing the second-year mechanics course to include computational methods. In addition, it is developing a signature program in surface physics and enhancing the programs in laser physics and computational physics with a $400,000 grant from the Keck Foundation and an additional $157,000 in matching funds from Lawrence University.

Indicators of Success:

1. The department graduates an average of 10 physics majors per year.
2. Since 1987, the department has received almost $2.5 million in external funding from Research Corporation, NSF, the Sloan Foundation, the Keck Foundation, and others.
3. Morale among students is very high, and students frequently expressed satisfaction with their relationships with faculty and fellow students as well as the preparation they were receiving for future graduate study or careers in physics.
4. Since 1991, GRE scores of graduates have risen appreciably, and many graduates receive awards such as NSF graduate fellowships, Clare Boothe Luce scholarships, a Rhodes scholarship, and a Hertz scholarship.
5. The department retains almost every major attracted into its program.
6. The sense of community that the physics department creates and the excellence of its program are well respected by other science faculty and the administration at Lawrence.

Keys to Making the Changes:

1. In the mid 1980s, two faculty members became dissatisfied with the department's record in graduating an average of five majors per year. These individuals played leading roles in revitalizing the physics program at Lawrence.
2. The president of Lawrence University has strongly supported changes in the physics program. The university has provided nearly one million dollars in matching funds to support the department's development and search for external funds.
3. The Research Corporation has provided the department with two external faculty consultants as well as advice from leaders of the Research Corporation to assist the president of the university and the department in making changes.
4. Students are expected to work hard in physics, but their interests are protected as members of the physics family. For example, faculty offices are smaller than offices in the other sciences so that there is room for a student study room/lounge in the corridor with the faculty offices.
5. Faculty view undergraduate education as their core mission and emphasize the view that an undergraduate physics program is much more than curriculum.

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