Institutional Effectiveness
2021-2022

Program: Physics BS

College and Department: College of Arts & Science – Department of Physics

Contact: Stephen Robinson

Mission: The mission statement for the TTU Department of Physics is to promote the learning of physics through effective teaching, research, and public service. Such learning opportunities are provided to students of all disciplines, in support of the mission of the University.

The department addresses this mission through two programs:

1. a coherent program of study leading to a B.S. in Physics, and
2. a service program that provides courses in physics and astronomy that are requirements for other degree programs or are used by students to fulfill general education science requirements.

Program Goals:

PG 1: The Department will recruit and retain sufficient majors for a thriving educational program.

Increase majors at least one per year. Having sustained an average of at least 30 majors for several years, the current minimum acceptable threshold is that the average number of majors should not drop below 30.

PG 2: The Physics Department will contribute to the mission of the Millard Oakley Center for Teaching and Learning in Science, Technology, Engineering, and Mathematics (STEM).

The majority of faculty in the department will support the center by teaching at least one class using its facilities and/or facilitating activities in center outreach events.

Physics students will engage in at least three center outreach activities per year.

PG 3: Ensure the use of effective and innovative pedogeological methods within the classroom.

All faculty will report on changes/innovation in instruction in their annual reports, reflecting on their utility with regard to student learning and attitudes. Changes that result in improved student performance are expected to be adopted and will be shared with the department as a whole. As a minimum, faculty are expected to report on one such strategy per year.

PG 4: Provide opportunities for all physics majors to gain experience in authentic basic or applied research.

All faculty engaged in research in suitable fields will seek support to engage interested physics majors in their work. Opportunities at other institutions and in other fields will also be made known to physics majors. The targeted outcome is that all physics majors will have the opportunity to engage in such opportunities as many times as they wish during their TTU career. At a minimum, any interested student should engage in at least one such opportunity.

Student Learning Outcomes:

SLO 1: Students completing calculus-based and algebra-based introductory physics courses will demonstrate increased understanding of foundational basic concepts in mechanics.

Students will achieve an average normalized gain score of at least 45% on a standard diagnostic test. For many years the targeted goal was a gain of 40%, but with recent improved performance, this year the target was raised to 45%. Currently, the minimum acceptable performance for any particular class section is a 30% gain, and any gain greater than 50% is regarded as exemplary.

SLO 2: Students graduating in physics will demonstrate an understanding of the basic principles and foundations of physics.

Graduating seniors will score, on average, at or above the 75^{th} percentile on the ETS Major Feld Test in Physics. The threshold of acceptability is to have all seniors score at or above the 50th percentile, thus maintaining a claim that TTU physics graduates are 'above average'.

SLO 3: Students graduating in physics will demonstrate the skills and techniques necessary to engage in authentic experimental investigation.

Students will demonstrate their ability to engage in experimental investigations by meeting or exceeding the minimum standards of the capstone Advanced Experimental Physics course (PHYS 4710 or PHYS 4711). The targeted outcome is that at least 75% of students should meet or exceed the minimum standards.

SLO 4: Students graduating in physics will demonstrate the ability to communicate their understanding orally in a presentation format.

Students will demonstrate their ability to effectively communicate their capstone Advanced Experimental Physics project (PHYS 4710 or PHYS 4711). The targeted outcome is that at least 75% of students should meet or exceed the minimum communication standards on the project rubric.

SLO 5: Students graduating in physics will have received an introduction to a range of common technological tools appropriate to physics and related disciplines.

All graduating physics majors and alumni report being adequately prepared to use technological tools appropriate to physics and related disciplines in their employment or graduate studies.

SLO 6: The TTU physics program will give students sufficient preparation in content and skills/techniques to continue to graduate school or obtain suitable employment.

All graduating seniors and alumni will report being well prepared to continue on to graduate school in physics (or a closely related discipline) or to enter immediate employment, whichever is relevant to their particular situation.

SLO 7: Students graduating in physics will demonstrate the skills and techniques needed to engage in planning and carrying out basic or applied research.

Students will demonstrate competency by completing a research project in PHYS 4730 (Research Planning) and PHYS 4740 (Research) courses taken as seniors. Students will meet or exceed the minimum standards of the research course (PHYS 4730 or PHYS 47140). The targeted outcome is that at least 75% of students should meet or exceed the minimum standards.

A departmentally developed curriculum map can be found in Appendix 1 that shows the connections between courses and student learning outcomes.

Assessment Methods:

PG 1: The Department will recruit and retain sufficient majors for a thriving educational program.

Department Records: At the beginning of each fall semester a count is made of the number of the total number of enrolled students who have Physics declared as a major. Because of the small numbers involved, trends are tracked using an average of the current year plus the previous four years. The department keeps a record of student participation in the research of department faculty members and in specialized summer research programs for undergraduates at other institutions. (Note: since almost all such experiences must necessarily take place during the summer it is impossible to ensure that all students will take advantage of such opportunities. However, the department will encourage such participation as actively as possible.) At the end of each academic year, a count is made of the number of actual or proposed projects, programs, and outreach events in which members of the Physics faculty and physics undergraduates were jointly involved with the Millard Oakley Center for Teaching and Learning in Science, Technology, Engineering, and Mathematics (STEM).

PG 2: The Physics Department will contribute to the mission of the Millard Oakley Center for Teaching and Learning in Science, Technology, Engineering, and Mathematics (STEM).

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PG 3: Ensure the use of effective and innovative pedogeological methods within the classroom.

Annual Faculty Reports: In their annual reports, faculty members will be asked to comment on their awareness of new pedagogical developments and whether they have tried to implement them in their own teaching.

PG 4: Provide opportunities for all physics majors to gain experience in authentic basic or applied research.

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SLO 1: Students completing calculus-based and algebra-based introductory physics courses will demonstrate increased understanding of foundational basic concepts in mechanics.

Force Concept Inventory: The Force Concept Inventory is a nationally recognized diagnostic test of basic conceptual understanding and is administered to all students at the beginning of both PHYS 2010 and PHYS 2110 courses, and then again after the relevant material has been covered. The normalized gain score, used to judge improvement in understanding, is a measure of the actual improvement in performance after instruction, versus the maximum possible improvement.

SLO 2: Students graduating in physics will demonstrate an understanding of the basic principles and foundations of physics.

Major Field Test: The ETS Major Field Test in Physics is a 70-item multiple-choice test that covers: Classical Mechanics and Relativity; Electromagnetism; Optics and Wave, Thermodynamics and Statistical Mechanics; Quantum Mechanics and Atomic Physics; and other Special Topics. All physics graduates will take the ETS Major Field Test in Physics during their final semester at TTU. Due to a low number of students, only two sub-scores are provided with the Exit exam results.

SLO 3: Students graduating in physics will demonstrate the skills and techniques necessary to engage in authentic experimental investigation.

PHYS 4710/4711 Capstone Course: All physics majors take a senior lab course, either PHYS 4710 (4 cr) or PHYS 4711 (2 cr). To be successful in this course students must synthesize many skills learned in their academic careers to date. They must engage in scientific investigation by planning and carrying out experiments, and they must use their physics knowledge to guide them and to interpret their results. They must also submit written reports of all their investigations and make a public oral presentation of one project at the end of the semester. Faculty present at these presentations will submit a report on them. A written summary of these reports, together with an assessment as to whether a particular student has met this outcome, will be compiled by the faculty member teaching the course, and placed in the student's file.

SLO 4: Students graduating in physics will demonstrate the ability to communicate their understanding orally in a presentation format.

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SLO 5: Students graduating in physics will have received an introduction to a range of common technological tools appropriate to physics and related disciplines.

Exit Interviews: Exit Interview with students who are getting ready to graduate from the program. While these students do not have the benefit of post-program experience, they do have a fresher recollection of their TTU experiences and so can provide valuable feedback on some elements of the program. The department chair already conducts a confidential exit interview with each graduating physics major. These interviews explicitly address how well prepared each student feels for their next career step, including their preparation in the use of technological tools and development of research skills.

Alumni Surveys: Because of the low number of physics graduates, the alumni surveys are administered to department alumni on an approximate 5-year cycle. Among the questions asked are how well graduates felt the TTU physics program prepared them for their chosen career path, and how effectively they were introduced to appropriate technological tools. (The most recent results available are from the survey conducted in Fall 2019 in conjunction with the department's scheduled academic audit.)

SLO 6: The TTU physics program will give students sufficient preparation in content and skills/techniques to continue to graduate school or obtain suitable employment.

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SLO 7: Students graduating in physics will demonstrate the skills and techniques needed to engage in planning and carrying out basic or applied research.

PHYS 4730 (Research Planning) and PHYS 4740 (Research) Capstone: All physics majors must take these two senior level research courses. To be successful in these courses, students must create a detailed research plan and present it both in written and oral formats (PHYS 4730). They must then conduct the planned research and again present the results in written and oral formats (PHYS 4740). Each year the department will judge students' competence in planning and conducting research and communication.

Results:

PG 1: The Department will recruit and retain sufficient majors for a thriving educational program.

The number of declared physics majors at the start of the Fall 2020 semester was 33. Though this represents increase of approximately 40% over the past two years, the 5-year average of 28.4 still remains below the minimum acceptable threshold of 30. During this year we continued several initiatives to improve recruitment and retention and, although hampered by the pandemic situation, these efforts have resulted in another large incoming class (relatively speaking) for the Fall 2022 semester.

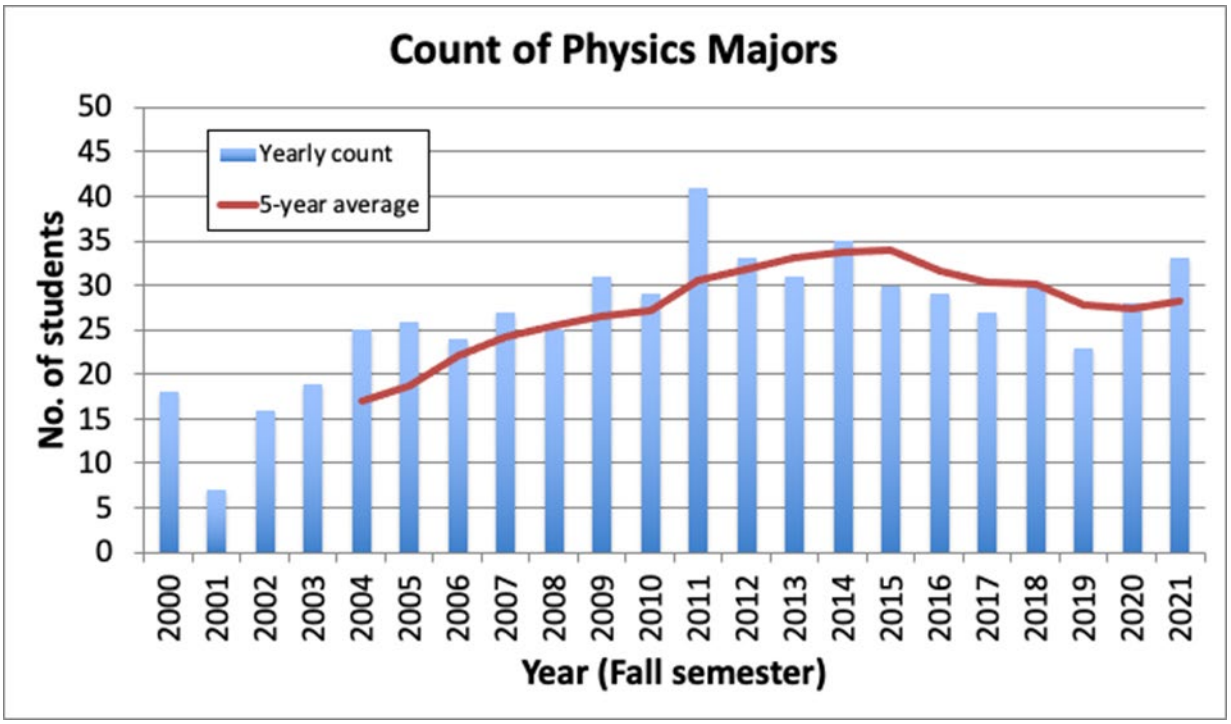

Fig 1. Number of students declaring a physics major at the start of each academic year.

One development of note is the number of incoming freshmen who have cited the astronomy-related opportunities we have recently started offering as playing a part in their decision to come to Tennessee Tech.

PG 2: The Physics Department will contribute to the mission of the Millard Oakley Center for Teaching and Learning in Science, Technology, Engineering, and Mathematics (STEM).

With the Department's move back from Foundation Hall this year, it is now much more practical (and convenient) to teach all our classes in the refurbished Bruner Hall. Hence, no PHYS or ASTR courses were taught using the facilities of the Millard Oakley STEM Center (MOSC). While two faculty members continued as PIs on separate grants administered by MOSC, physics students engaged in only one outreach event offered by the center. Thus, we did not meet the target for either faculty or student involvement.

We anticipate this much-reduced involvement with MOSC continuing for the foreseeable future and so, for reasons discussed in another section of this report, we have decided that this goal has been completed and will be replaced with another goal driven by our developing capabilities in astronomy.

PG 3: Ensure the use of effective and innovative pedagogical methods within the classroom.

All faculty reported that they tried at least one different strategy in their classes this year. Although some of this was due to the continued restrictions imposed by the COVID-19 pandemic, other innovations include:

- Reading quizzes and group-work/breakouts in lecture classes.
- Two-stage quizzes, including group collaboration.
- Video presentation of group projects.
- Introduction of more computational assignments in upper division courses.
- Using shared Google documents to keep track of student progress and thinking in active-learning classes.
- Use of the Vivi software to allow students to display their work in class.
- Use of interactive student polling in more classes.
- Development of new interactive class materials for ASTR courses.

PG 4: Provide opportunities for all physics majors to gain experience in authentic basic or applied research.

During this year a total of sixteen individual undergraduate students participated in research activities of various types with department faculty members. Given the continued restrictions imposed by the COVID-19 pandemic during at least part of the year, it is remarkable that we were able to sustain such high student involvement. (Additionally, the graduate student in the College of Education being mentored by two physics faculty members gained her PhD during the year.) Of note is that, for the second year, the two students gained their research experiences in astronomy-related projects. All physics majors who desired such an experience were accommodated, thus achieving the target for this goal.

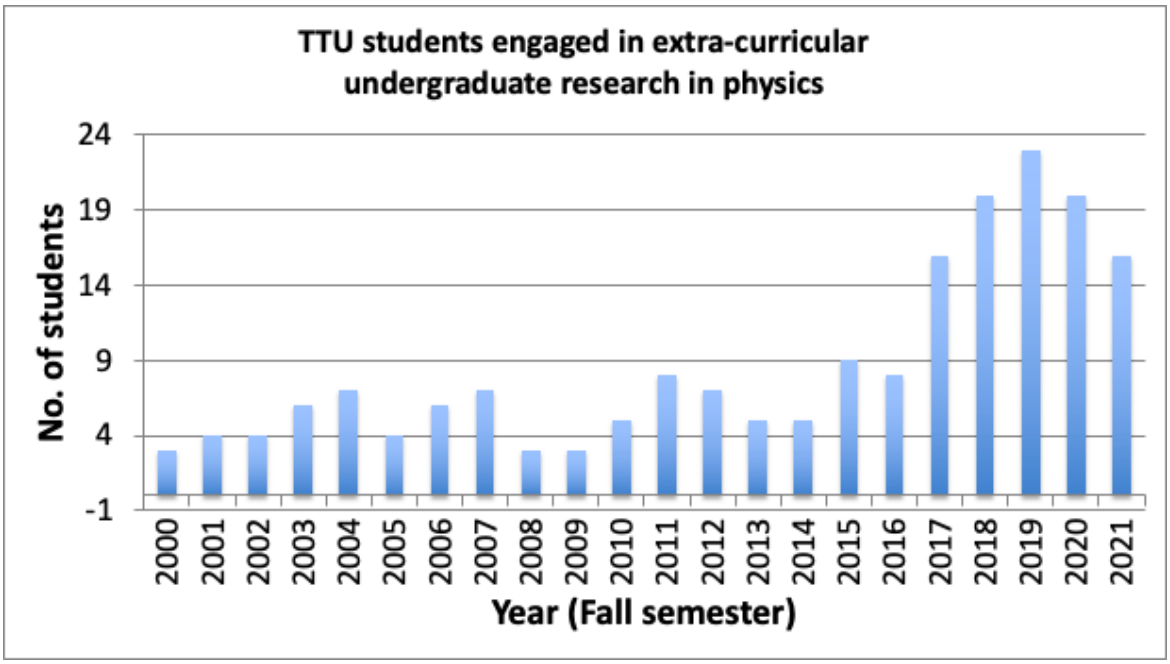

Fig 2. Number of undergraduate students engaged in extra-curricular research.

SLO 1: Student Learning Outcome 1 - Students completing calculus-based and algebra-based introductory physics courses will demonstrate increased understanding of foundational basic concepts in mechanics.

In each of the Fall and Spring semesters, four PHYS 2110 sections were delivered in-person, with an additional section using an asynchronous online format. Of these only one in-person section in each semester attained the goal of a 45% gain. In fact, each of these two sections easily surpassed the 'exemplary' bar of a 50% gain. Unfortunately, over the course of the year, five sections did not attain the minimum acceptable performance of a 30% gain. Folding in these results, the rolling 5-semester average gain now stands at 39%, dropping below the 45% goal that was surpassed for the first time last year. The reason for the drop in performance this year is not clear, but since this diagnostic test focuses on conceptual understanding, the department has decided that going forward, there will be more emphasis on this on quizzes and tests in this course. Hopefully, this will encourage students to take this aspect of their learning more seriously.

Turning to PHYS 2010, all sections returned to being taught in-person. This is much more preferable as almost all sections of this course are taught in a an active-learning style (LEAP) that emphasizes student collaboration and interaction. Of the six sections taught in this format, four surpassed the goal of a 45% gain, with three also surpassing the 'exemplary' bar of a 50% gain. The other two sections easily exceeded the minimum acceptable performance of a 30% gain We continued to offer one section of PHYS 2010 in the more traditional manner, but low registration in this section meant that no meaningful data could be collected. Past history shows that gains of less than 20% are typical for this format and so, for the Fall 2022 semester, and going forward, we now have the necessary resources than mean we can offer all sections using the LEAP format.

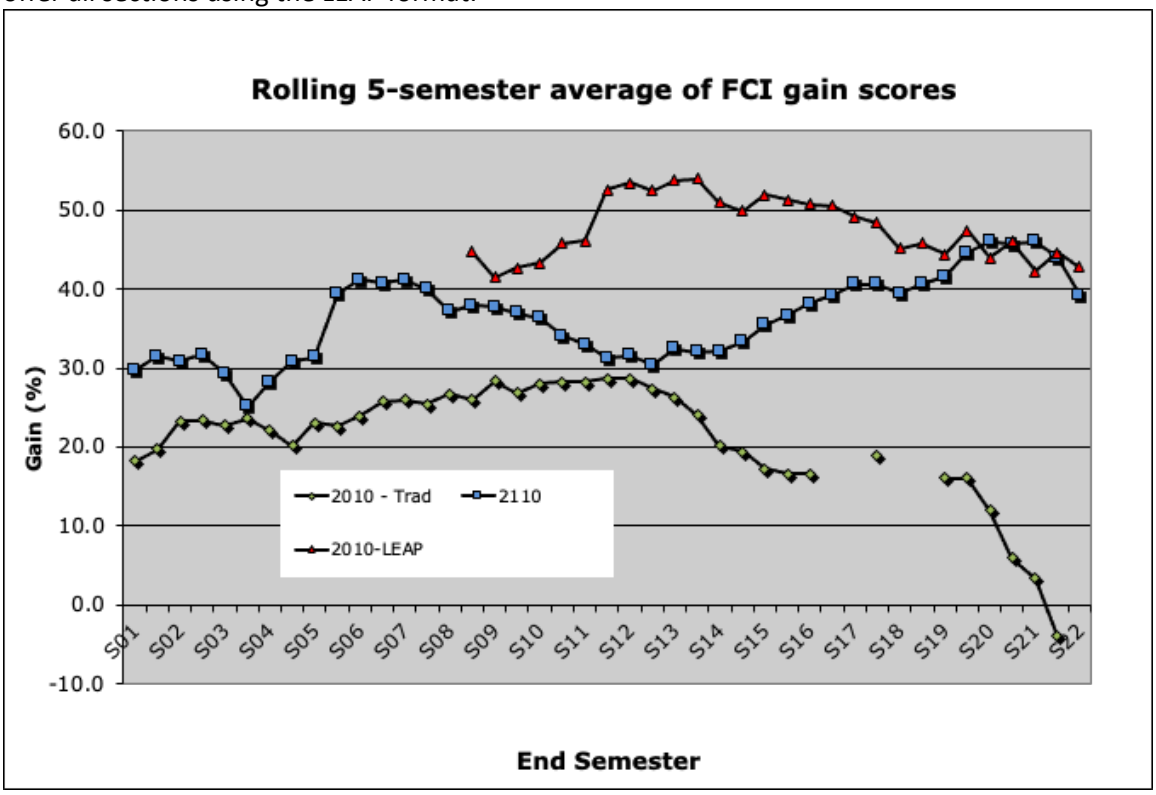

Fig 3. Rolling 5-semester average of FCI gain scores.

SLO 2: Student Learning Outcome 2 - Students graduating in physics will demonstrate an understanding of the basic principles and foundations of physics.

Major Field Test: Three graduating seniors took the Major Field Test this year, placing (on average) at the 61st percentile. This is a better result than last year, easily exceeding our minimum acceptable target of the 50th percentile, but still falls below our aspirational target of the 75th percentile. However, these students' junior and senior years were severely affected by the pandemic situation, whereas the percentile rankings are determined using several years of national data. This puts our three-year average percentile ranking at 63, but we will wait to propose any action until we see if the current downward trend continues as circumstances return to normal.

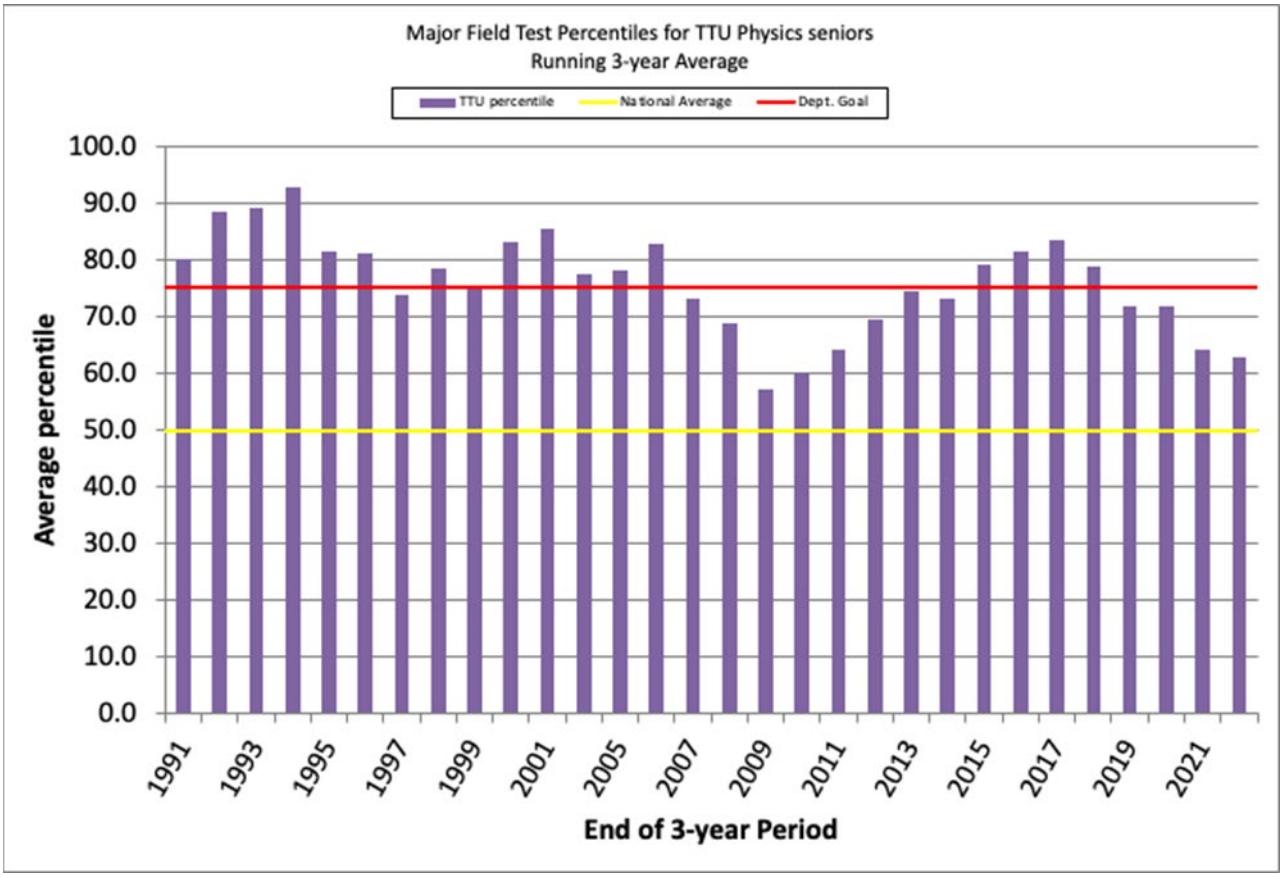

Fig 4. Rolling 3-year average of physics majors' Major Field Test percentiles.

Alumni Survey: A full report of our most recent survey in Fall 2019 is attached, but significant results in the context of this SLO are:

- Alumni continue to be highly satisfied with the program and the overall level of preparation they receive for their future careers.
- The standard of preparation in Classical Mechanics and Thermodynamics is consistently rated as somewhat weaker than that in other topics.

SLO 3: Student Learning Outcome 3 - Students graduating in physics will demonstrate the skills and techniques necessary to engage in authentic experimental investigation.

All five of the physics majors who took the PHYS 4710 course this year met or exceeded the minimum standards, as judged by the instructor, meaning that the target for this goal was attained. However, in order to put the assessment of this goal on a more qualitative footing, the instructors for this course are developing a rubric to measure the degree to which students demonstrate the required skills. We anticipate this rubric being completed in time for assessing students in the coming year.

SLO 4: Student Learning Outcome 4 - Students graduating in physics will demonstrate the ability to communicate their understanding orally in a presentation format.

Five physics majors took the PHYS 4710 course this year. All were judged by the faculty to have made acceptable oral presentations, attaining the target for this goal. This year we trialled the attached rubric for assessing the quality of these presentations. During the coming year we will fine-tune the wording and weighting in this rubric to better fit with faculty expectations and then decide on scores corresponding to levels of attainment for assessing this goal.

SLO 5: Student Learning Outcome 5 - Students graduating in physics will have received an introduction to a range of common technological tools appropriate to physics and related disciplines.

Exit Interview: Exit interviews were conducted with three graduating seniors this year. All felt that they had been adequately exposed to relevant commercial software and opportunities to practice their own coding in a physics context, but two also expressed that they would have welcomed more such opportunities to 'solidify' these skills.

Alumni Survey: A full report of our most recent survey in Fall 2019 is attached, but relevant to this SLO, alumni reported that preparation in terms of using software and coding was ‘adequate’ to ‘good’. This seems to correspond to the views expressed by graduating seniors in their exit interviews.

Student Learning Outcome 6 - The TTU physics program will give students sufficient preparation in content and skills/techniques to continue to graduate school or obtain suitable employment.

Exit Interview: Exit Interviews were conducted with three graduating seniors this year. All were intending to go to graduate school in physics, or a closely related discipline, though two had decided to take a 'gap' year before doing so. All three deemed their preparation for graduate school to be good.

Alumni Survey: A full report of our most recent survey in Fall 2019 is attached, but relevant to this SLO, alumni continue to report being highly satisfied with the program and the overall level of preparation they receive for their future careers.

Student Learning Outcome 7 - Students graduating in physics will demonstrate the skills and techniques needed to engage in planning and carrying out basic or applied research.

PHYS (Research Planning) and PHYS 4740 (Research) courses: Three students completed the research course sequence this year and met the minimal standards for success, thus demonstrating their attainment of the required skills and in planning and carrying out research. Two more students were

successful in PHYS 4730, but did not complete PHYS 4740, so a full assessment of their attained research skills cannot yet be made.

Research Involvement: During this year a total of sixteen individual undergraduate students participated in research activities of various types with department faculty members. Given the continued restrictions imposed by the COVID-19 pandemic during at least part of the year, it is remarkable that we were able to sustain such high student involvement. All physics majors who desired such an experience were accommodated.

Exit Interviews: Exit Interviews were conducted with three graduating seniors this year. All were of the opinion that their research experience was extremely valuable and worthwhile.

Alumni Survey: A full report of our most recent survey in Fall 2019 is attached, but relevant to this SLO, alumni continue to report their research involvement as being one of their most valuable undergraduate experiences.

Modifications for Improvement:

The LEAP curriculum is a set of materials developed by two faculty members in Physics for use in the algebra-based physics course sequence (PHYS 2010 and PHYS 2020). These activity-based materials use a very different pedagogical structure than traditional lecture courses and their implementation involves the integration of lecture and lab periods in a seamless manner. Very soon after their initial implementation it became clear that students in course sections that used these materials performed much better on the diagnostic test used to assess the Learning Outcome than those in traditionally taught sections.

With faculty training we have been able to gradually increase the number of sections taught using these materials, but lack of resources (including difficulties in scheduling appropriately equipped rooms) meant we always had to offer at least one section in the traditional format. However, with our move back to the refurbished Bruner Hall, and an investment in new equipment, we have been able to dedicate two lab rooms exclusively to LEAP format classes. This means that going forward we will be able to offer all sections of both PHYS 2010 and PHYS 2020 in the LEAP format, thus ensuring all students in these courses benefit from the improved learning this class format promotes.

Previously, the assessment of Learning Goals 3 (Experimental Skills), 4 (Communication Skills), and 7 (Research Skills) was done by faculty using their own, somewhat subjective, judgement. In order to put these assessments on a more consistent basis the department is in the process of establishing specific measures that can be used to identify the degree to which individual students have attained the desired skills.

For Learning Outcome 4 (Communication Skills), during the past year we established a rubric that faculty can use to assess student presentations. (It is attached to the results section for Learning Outcome 4.) The inter-rater consistency of this assessment was trialled for student presentations in the PHYS 4710 course and the department is now satisfied that this will be a functional measure. During this year we will establish what scores and sub-scores in the rubric will be taken to correspond to different levels of student communication skills, and implement these for this year's PHYS 4710 presentations.

For Learning Outcomes 3 (Experimental Skills) and 7 (Research Skills), the department has discussed what skills are important for students to demonstrate in the relevant courses, but has not yet agreed on a final list. Our plan for the coming year is to finalize these lists in a manageable form and then develop draft rubrics that can be trialled in the relevant courses.

Based on student and faculty interest, recently the department initiated a course in Observational Astronomy (ASTR 3100) and, jointly with the Department of Earth Sciences, a minor program in astronomy. We have noted at recruitment events that both of these developments seem attractive to prospective students, tipping the balance in persuading some to choose Tennessee Tech for their undergraduate studies. Further, by working with programs run by other institutions, we have been able to offer astronomy-related research experiences to several students over the past two years. Students' positive reactions to these initiatives have suggested to us that an enhancement of our astronomy capability could serve as an attractive recruiting and retention tool. To this end, with the agreement of the College of Agriculture and Human Development, we have planned the development of a permanent astronomical observing site at a suitable location on TTU's Oakley Farm. Funding via grants, department funds, and a generous donation, has already been obtained to begin construction. We believe this facility will have an influence on both learning outcomes and program goals.

A permanent facility will allow us to run regular outreach events open to the general public. In addition, we envisage dedicated outreach to area high schools, involving training teachers and students to plan their own observations and take a role in implementing them. This, coupled with exposure to the research opportunities available to Tech students, will hopefully prove to be an attractive recruitment tool (Program Goal 1). In addition, the astronomical research capability of this facility, will provide further opportunities for Tech students to explore different career options (Learning Outcome 6) and enhance their experiments and research skills (Learning Outcome 7 and Program Goal 4).

Appendices

1. Physics BS Curriculum Map

Appendix 1: Physics BS Curriculum Map

Support for core goals and learning outcomes in the program of study for a B.S. in Physics.

		Goals/Learning Outcomes					
Course	Title	Physics knowledge	Analytical skills	Laboratory skills	Communication skills	Computer skills	Research experience
PHYS 1137	Frontiers of Physics	X					
PHYS 2110	Calculus-based Physics I w/lab.	X	X	X			
PHYS 2120	Calculus-based Physics II w/lab	X	X	X			
PHYS 2420	Modern Physics	X	X		X	X	
PHYS 2920	Mathematical Physics		X		X	X	
PHYS 3610	Classical Mechanics	X	X		X	X	
PHYS 4610	Classical Elec. & Mag. I	X	X		X	X	
PHYS 4620	Classical Elec. & Mag. II	X	X		X	X	
PHYS 3120	Statistical Thermal Physics	X	X		X	X	
PHYS 3810	Quantum Mechanics I	X	X		X	X	
PHYS 3820	Quantum Mechanics II	X	X		X	X	
PHYS 4710/ PHYS 4711	Advanced Experimental Physics	X	X	X	X	X	
PHYS 4130	Computational Physics		X		X	X	
PHYS 4130	Research Planning	X	X	X	X	X	X
PHYS 4140	Research	X	X	X	X	X	X