Institutional Effectiveness
2023-2024

Program: Physics BS
College and Department: College of Arts and Sciences, Department of Physics
Contact: Stephen Robinson
Mission:

The TTU Department of Physics will promote the learning of physics and astronomy 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 various programs:

- a major program of study, with two options, leading to a B.S. in Physics
- programs of study leading to minors in Physics and Astronomy
- 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.

Attach Curriculum Map (Educational Programs Only):
Attached Files: See Appendix 1

Learning Outcome 1 - Student Learning in Introductory Courses

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

Assessment Methods:
Understanding of basic mechanics concepts will be measured using the nationally recognized Force Concept Inventory, a standard diagnostic test used at many institutions nationwide. It will be 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 will be used to judge improvement in understanding, and is a measure of the actual improvement in performance after instruction versus the maximum possible improvement.

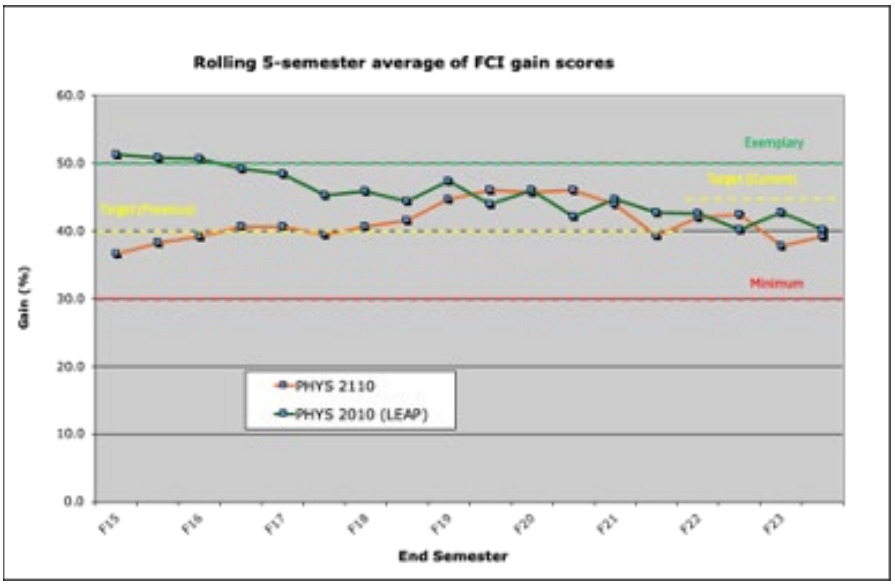
Criteria for Success (Thresholds for Assessment Methods):
For many years the targeted goal was a gain of 40%, but with recent improved performance, the target has now been raised to 45%. Currently, the minimum acceptable performance for any particular class section is a 30% gain, and any gain greater than 50% is regarded as exemplary.

Link to 'Tech Tomorrow' Strategic Plan:
1.B General Education Curriculum,1.D High Impact Practices

Results and Analysis:
The table below shows how sections of the targeted courses performed this year, in terms of the thresholds defined for this outcome.

Course	Total sections	Below minimum (<30%)	Acceptable (30% - 44%)	Attained target (45% - 50%)	Exemplary (>50%)
PHYS 2010	5	1	3	2	0
PHYS 2110	7	3	2	0	1

The following graph shows a rolling 5-semester average for the performance of the two courses since 2015.



The historical trend in PHYS 2110 showed a gradual improvement, which prompted the raising of the target for this outcome to a 45% gain two years ago. However, this year's results for PHYS 2110 were disappointing, with only one section surpassing the target of a 45% gain, and three falling below the minimum. The likely reasons for this were that; i) one of our higher performing instructors in this course has now retired and, ii) there was a major disruption during the spring semester when another instructor for this course passed away unexpectedly.

The performance in PHYS 2010 improved slightly over last year, with two sections attaining the target gain, and only one being below minimum. This course has historically performed well in regard to this outcome, but the graph shows the average gains trending slightly downward over the past few year. A likely reason for this is that, following the reconfiguring of the university's instructional schedule, some topics that are addressed by this diagnostic test are being given less time (or not covered at all).

Use of Results to Improve Outcomes:

While performance in PHYS 2110 was disappointing this year, due to the extenuating circumstances in this course, we will continue to promote the use of student-centered instructional strategies in this course that we think have been responsible for improvement over the long term.

The situation in PHYS 2010 remains more complicated and we continue to discuss reasons for the recent drop in performance. It is possible that simply making changes in emphasis/ordering will allow us to again cover all the topics addressed by the diagnostic test. However, it is possible that doing so could affect observed improvements in other areas of the course not addressed by this diagnostic test, such as quantitative problem solving. This is an ongoing topic of discussion in the department that we hope to resolve in the coming year by examining several years of data to determine whether the gradual decline can be attributed to poorer performance on items associated with particular content areas.

Learning Outcome 2 - Learning of Physics Majors

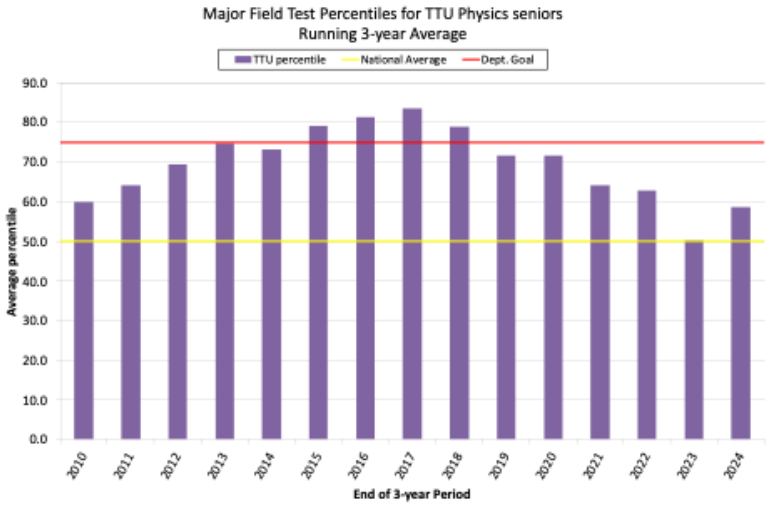
Define Outcome:
Students graduating in physics will demonstrate an understanding of the basic principles and foundations of physics.

Assessment Methods:
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.

Criteria for Success (Thresholds for Assessment Methods):
The aspirational target is that graduating seniors will score, on average, at or above the 75th percentile on the ETS Major Feld Test in Physics, both on their overall score, and also on the two reported sub-scores. The threshold of acceptability is to have an average at or above the 50th percentile, thus maintaining a claim that TTU physics graduates are 'above average'.

Link to 'Tech Tomorrow' Strategic Plan:
4.B Programs, Certificates, and Training

Results and Analysis:
The two physics majors who took the Major Field Test this year scored, on average, at the 90^{th} percentile, with both easily surpassing the 75^{th} percentile target. Because of low numbers, it is difficult to base decisions on a single year's scores. Therefore, we use a rolling three-year weighted average to examine trends. These results bring the three-year average up to the 59^{th} percentile which is a definite improvement from last year, as shown on the graph. However, it will take another two years for last year's poor results to work through our three-year average.



The table below shows the averages of sub-scores on the two portions of the Major Field Test (Introductory and Advanced Physics) reported on a scale of 20-100, with the national average being approximately 50. The goal of an average at or above the 75th percentile corresponds to a sub-score of approximately 62 in each portion.

Year	Students tested	Sub-scores[2]	
		Introductory Physics	Advanced Physics
2010/11	3	57	61
2011/12	1	59	61
2012/13	5	58	68
2013/14	3	58	69
2014/15	3	61	70
2015/16	2	64	70
2016/17	3	65	69
2017/18	1	61	68
2018/19	5	59	63
2019/20	Due to Covid-19 pandemic, graduating seniors did not take test		
2020/21	2	55	60
2021/22	3	52	61
2022/23	5	44	56
2023/24	2	70	72

These latest sub-scores seem to counter the pattern that emerged over the previous years, in that our majors seemed to perform more poorly on introductory topics than they do on advanced topics. Nevertheless, we will continue to focus our efforts on improving our majors' understanding of introductory topics until this pattern is no longer apparent over a longer time scale.

Use of Results to Improve Outcomes:

In discussing the long-term trend in sub-scores, the faculty have now identified and implemented several strategies to better help physics majors develop a deeper understanding of introductory topics. Much of this is being done in collaboration with the Physics Club:

- An emphasis on cohort building to encourage collaborative learning.
- Mentoring of freshmen and sophomores by upperclassmen.
- Closer tracking of physics majors in their introductory physics classes, to quickly identify when additional help is needed.
- Increasing the frequency of recitation/help/review sessions, which targeted physics majors will be encouraged to attend.
- Faculty reviewing and making connections to relevant introductory materials in more advanced classes.

Learning Outcome 3 - Physics Skills

Define Outcome:

Outcome: Students graduating in physics will demonstrate a range of competencies necessary to pursue a physics-related career. In particular, they will demonstrate the skills and techniques needed to:

- engage in authentic experimental investigation.
- communicate their work in a written format.
- communicate their work in an oral presentation format.
- use appropriate computational tools and techniques.
- engage in planning and carrying out basic or applied research.

Assessment Methods:

During their senior year, all physics majors take the following capstone set of courses:

- Advanced Experimental Physics (either PHYS 4710 (4 cr) or PHYS 4711 (2 cr))
- Computational Physics (PHYS 4130)
- Research Planning (PHYS 4730) and Research (PHYS 4740)

To be successful in this set of courses, students must apply and synthesize all of the skills addressed by this outcome, thus providing the opportunity to assess their degree of competency. In some cases, assessments of these skills may also be carried out in extracurricular contexts, such as summer research internships, student seminars, and conference presentations. The matrix below summarizes which skills may be assessed in which courses/context.

	Senior Level Courses			Extracurricular (if applicable)	
Skill	PHYS 4710/4711	PHYS 4130	PHYS 4730/4740	Research Experience	Seminar/ Conference
Experimental Investigation	X	?	X	X	
Written Communication	X	X	X	X	
Oral Communication	X	X	X		X
Computation		X	?	?	
Basic/Applied Research	?		X	X	

X = Definite context for assessment ? = Possible context for assessment

Each of these sets of skills will be assessed using agreed upon rubrics that are currently under development and pilot testing. Depending on the context, these rubrics will be used by course instructors, research supervisors, and other faculty.

Criteria for Success (Thresholds for Assessment Methods):
Once pilot testing of the various rubrics is complete, criteria for success will be set by the whole department. It is the intention that criteria will be set both for each set of skills separately, and for the ensemble as a whole.

Link to 'Tech Tomorrow' Strategic Plan:
1.D High Impact Practices,2.A Technology Infused Programs

Results and Analysis:
During the year, the physics faculty worked on refining an initial set of physics skills outcomes, to make them more concise and easier to assess. A first draft of associated rubrics were developed and used to assess two graduating seniors, and other majors in applicable contexts. The current outcomes and rubrics are attached.

For the two graduating seniors, each skill was assessed in one to four contexts during the year. The number of students that fall into each rubric category for each skill are shown in the Table 1 below. The 'Overall' assessment was determined by averaging the individual skill assessments for each student.

Table 1. Level of attainment of Physics Skills for physics majors graduating during the 2023/24 academic year (N=2).

Skill	Exceeds Expectations	Meets Expectations	Developing-High	Developing-Low	No evidence
Experimental Investigation	1	1			
Written Communication	1	1			
Oral Communication		2			

Computation	2				
Research	2				`
Overall	1	1			

Since these assessments were still under development during the year, the faculty has not yet agreed on definite targets, but the performance of these two students in meeting or exceeding expectations will serve as a benchmark as this is done.

In addition to the two graduating seniors, some of the assessments were applied to other physics majors in applicable contexts, the results of which are shown in Table 2. It should be noted that these assessments are intended only as a means to provide formative feedback to those students, and will not be taken into account in any final analysis. They also provided opportunities for faculty to become more familiar with the outcomes and rubrics.

Table 2. Level of attainment of Physics Skills for other physics majors during the 2023/24 academic year.

Skill	Exceeds Expectations	Meets Expectations	Developing-High	Developing-Low	No evidence
Experimental Investigation	2	1	1		
Written Communication	3	1			
Oral Communication	5	2			
Research	2				`
Overall	3	1	1		

Attached Files: See Appendix 2

Use of Results to Improve Outcomes:
With the outcomes and rubrics in close to final form, the department is now in a position to establish aspirational and minimum acceptable targets. This will be done in the coming months, using this year's assessments as benchmarks. With the low number of graduates, it will take some time to gather enough data to see if changes in student preparation are needed.

Therefore, we see the immediate impact of these assessments as a structure to give formative feedback to students as they develop these skills before their senior year.

Learning Outcome 4 - Career Preparation

Define Outcome:
Graduates of the TTU physics program will agree that the program gave them a well-rounded, scientifically and technologically grounded preparation, with strong analytical skills, such that they were well prepared for their next career step.

Assessment Methods:

- **Exit Interviews**: While students who are getting ready to graduate from the program 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. In their exit interviews, students will be explicitly asked about how well prepared each student feels for their next career step, both overall and in terms of individual elements.
- **Alumni Surveys**: Because of the low number of physics graduates, surveys are administered to department alumni on an approximate 5-year cycle. Among the questions asked are how effectively graduates felt the TTU physics program prepared them for their chosen career path.

Criteria for Success (Thresholds for Assessment Methods):
All graduating seniors and alumni will agree that the program prepared them well 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.

Link to 'Tech Tomorrow' Strategic Plan:
1.A Experiential Learning,1.D High Impact Practices,4.B Programs, Certificates, and Training

Results and Analysis:

- **Exit Interview:** Exit Interviews were conducted with two graduating seniors this year. Both were intending to go to graduate school in physics, and deemed their preparation for graduate school to be good.
- **Alumni Survey:** A survey was conducted in Fall 2023 and 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.

With these results it seems this learning objective continues to be met.

Attached Files: See Appendix 3

Use of Results to Improve Outcomes:
No action is deemed necessary at this time.

Program Goal 1 - Number of Physics Majors

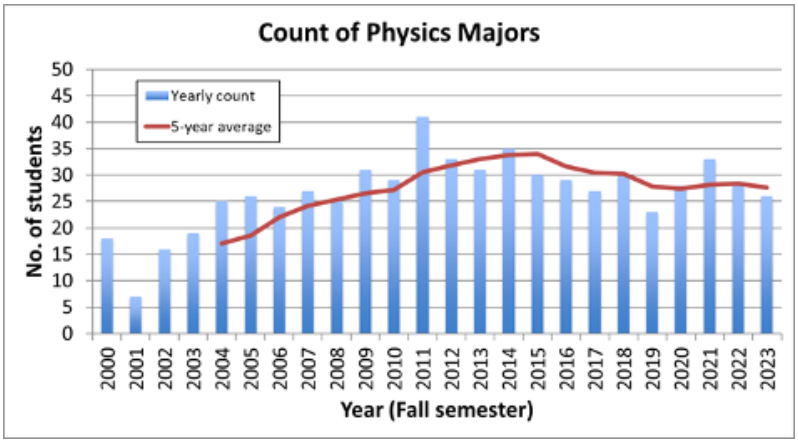
Define Outcome:
The Department will recruit and retain sufficient majors for a thriving educational program.

Assessment Methods:
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 chair maintains a spreadsheet that tracks these numbers.

Criteria for Success (Thresholds for Assessment Methods):
The current target is that this average will increase by 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.

Link to 'Tech Tomorrow' Strategic Plan:
4.B Programs, Certificates, and Training

Results and Analysis:
At the start of this year the number of students declaring a physics major was 26, keeping the 5-year average at around 28.5, which is still below the minimum threshold of 30. In fact, despite small year-to-year fluctuations, the average continues to stay very close to this threshold.



Use of Results to Improve Outcomes:
Despite our efforts to raise our profile during university-wide recruitment efforts, the 5-year average still hovers around the minimum threshold.

Unfortunately, due to the loss of a faculty position and the sudden death of another faculty member, we were unable to begin our planned outreach program to area high schools. We hope to begin this in the coming year. Meanwhile, following recommendations from our program review conducted this year, we are discussing how to restructure our programs of study to make them more attractive to a broader range of potential recruits.

Program Goal 2 - Improving Instruction

Define Outcome:
Ensure the use of effective and innovative pedagogical methods within the classroom.

Assessment Methods:
In their annual effort reports, all faculty will be expected to report on changes/innovation in instruction, reflecting on their utility with regard to student learning and attitudes. Changes that result in improved student performance will be shared with the department as a whole.

Criteria for Success (Thresholds for Assessment Methods):
As a minimum, every faculty member is expected to report on at least one such strategy per year, together with an assessment of its effectiveness.

Link to 'Tech Tomorrow' Strategic Plan:
1.A Experiential Learning,1.B General Education Curriculum,1.D High Impact Practices,4.B Programs, Certificates, and Training

Results and Analysis:
This was a hard year for the department in terms of instructional load for individual faculty. First, we lost a faculty position, and then another faculty member passed away suddenly. This meant most faculty took on increased loads and had less time to prepare for, and assess, any new teaching strategies.

Nevertheless, four faculty did take on the task on implementing completely online versions of our calculus-based physics courses, both lecture and lab. These faculty reported on innovations in terms of both implementation and assessment that seemed to have positive results in terms of significantly reducing DFW rates.

Use of Results to Improve Outcomes:
The apparent success of the innovative approaches to assessments and lab outcomes in the online sections will be shared with the whole department before the Fall 2024 semester and inform a discussion of possible changes to the on-ground sections. This meshes nicely with a recommendation from our recent program review to consider revising our calculus-based introductory courses to make them more relatable to students.

Program Goal 3 - Undergraduate Research Experience

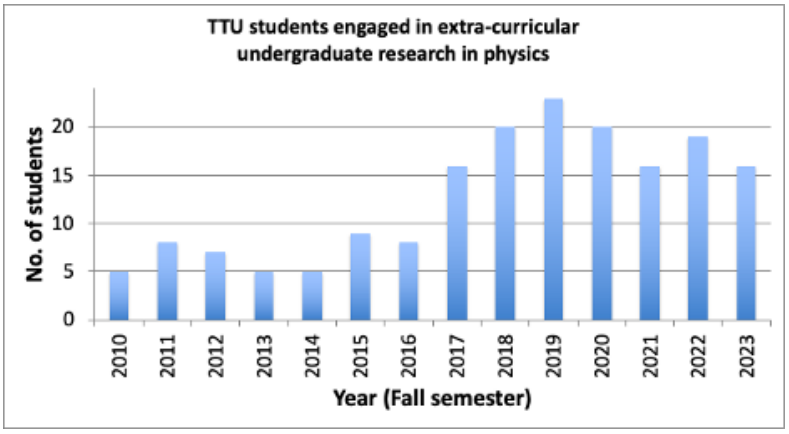
Define Outcome:
All physics majors will have the opportunity to gain experience in basic or applied research.

Assessment Methods:
The department chair will keep a record of student participation in the research of department faculty members and in specialized programs for undergraduates at other institutions (e.g. REUs and SULIs). (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.)

Criteria for Success (Thresholds for Assessment Methods):
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.

Link to 'Tech Tomorrow' Strategic Plan:
1.A Experiential Learning,1.D High Impact Practices,2.B Research, Scholar, Intellect, and Creativity

Results and Analysis:
During this year a total of sixteen individual undergraduate students participated in research activities of various types with department faculty members. This continues the high level of involvement of the past several years, which is built on the deliberate recruitment of faculty members who are committed to such undergraduate engagement. All physics majors who desired such an experience were accommodated, thus achieving the target for this goal.



Use of Results to Improve Outcomes:
With this goal currently being achieved, we will maintain our current strategies of broadly publicizing research opportunities and requiring a commitment to undergraduate research in future tenure-track faculty searches.

Summative Evaluation:

- Recruitment of sufficient numbers of physics majors to maintain a thriving program. As well as continuing current efforts, this will be further addressed by revising our programs of study to hopefully make them more attractive to prospective students. This is in line with recommendations from the external program review conducted during the past year.
- Declining overall Major Field Test scores for Physics majors, and the lower performance on the Introductory Physics sub-score. This year's graduating cohort did much better in both these aspects, but the numbers are too small to draw any conclusions as to whether the measures we took last year were truly effective. We will therefore continue to monitor these trends.
- Gradual decline in diagnostic testing scores in PHYS 2110. In order to examine whether this decline is due to less time spent on certain content areas, during this coming year we will examine several years of data to determine whether the gradual decline can be attributed to poorer performance on items associated with those content areas.

Assessment Plan Changes:
During the last year we developed and applied a set of learning objectives and rubrics to be used in assessing Learning Outcome 3, which addresses the skills and techniques we want our physics majors to acquire through their courses, and other experiences within the department. During the coming year, based on this experience, we will finalize these objectives and rubrics. We will also set targets for both individual objectives and their overall ensemble. In addition we will develop a protocol for using them to give formative feedback to physics majors who are not yet in their senior year.

List of Appendices:
Appendix 1: Curriculum Map
Appendix 2: SLO3 Results
Appendix 3: SLO4 Results

Appendix 1: Curriculum Map

		Goals/Learning Outcomes					
Course	Title	Physics knowledge	Analytical skills	Laboratory skills	Communication skills	Computational skills	Research experience
PHYS 1137	Frontiers of Physics	X			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	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	X	

PHYS 4130	Research Planning	X	X	X	X	X	X
PHYS 4140	Research	X	X	X	X	X	X

Appendix 2: SLO3 Results

Computational skills -Outcomes-v1-2

Computational skills – Draft Student Learning Outcomes

1. Students will be able to demonstrate mastery of techniques in computational physics by:
    a. Translating a model into code.
    b. Choosing scales and units that simplify coding.
    c. Subdividing a computational model into a set of manageable computational tasks.
    d. Implementing a variety of algorithms and computational tools.
    e. Debugging, testing, and validating code.
    f. Extracting physical insight from a computation.

Rubric

Above Expectations	Meets Expectations	Developing – High	Developing – Low	Insufficient evidence
At least three subskills demonstrated with high degree of competency. Others with reasonable degree of competency.	At least four subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency.	Three subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency. OR Four subskills demonstrated with reasonable degree of competency or higher. Others not demonstrated.	Two subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency. OR Three subskills demonstrated with reasonable degree of competency or higher. Others not demonstrated.	Two or fewer demonstrated, but not to appropriate standard.

Where/when to apply skills assessments

	Courses			**Extracurricular (if applicable)**	
Skills	**PHYS 4710/4711 (Adv. Lab.)**	**PHYS 4130 (Comp. Phys.)**	**PHYS 4730/4740 (Research)**	**Research Experience**	**Seminar/ Conference**
Computation		X	?	?	

X = Definite context for assessment
? = Possible context for assessment

Oral Communication -Outcomes-v1-2

Oral Communication – Draft Student Learning Outcomes

2. Students will be able to give an oral report of an investigation that adheres to the following guidelines:
    a. Information is presented in a logical sequence that the audience can follow.
    b. Is of the appropriate length for the context in which it is made.
    c. Engages with the audience as much as possible.
    d. Is presented in a clear voice that is audible to all audience members.
    e. Demonstrates appropriate familiarity with background material related to the topic.
    f. Uses visual aids (slides/poster) that follow the flow of the presentation, have a reasonable information density, and are legible for the audience.

Rubric

Above Expectations	Meets Expectations	Developing – High	Developing – Low	Insufficient evidence
At least four subskills demonstrated with high degree of competency. Others are reasonable.	At least four subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competencycy.	At least three subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency. OR Four subskills demonstrated with reasonable degree of competency or higher. Others not demonstrated.	Two subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency. OR Three subskills demonstrated with reasonable degree of competency or higher. Others not demonstrated.	Two or fewer demonstrated, but not to appropriate standard.

Where/when to apply skills assessments

	Courses			Extracurricular (if applicable)	
Skills	**PHYS 4710/4711 (Adv. Lab.)**	**PHYS 4130 (Comp. Phys.)**	**PHYS 4730/4740 (Research)**	**Research Experience**	**Seminar/ Conference**
Oral Communication	X	X	X		X

X = Definite context for assessment
? = Possible context for assessment

Written Communication -Outcomes-v1-2

<u>Written Communication – Draft Student Learning Outcomes</u>

3. Students will be able to construct a written report of an investigation that adheres to the conventions of scientific writing, including:
    g. A title that is descriptive of the investigation.
    h. An abstract that summarizes the investigation, its results, and conclusions.
    i. An introductory section that clearly states what was investigated, gives a rationale, and reviews prior work.
    j. A procedure section that describes the equipment and materials used, and clearly and concisely describes the experimental methods used.
    k. A results section that includes appropriately formatted data tables and graphs. When appropriate it should also discuss any data fitting done and how the 'goodness of fit' was determined.
    l. A discussion/conclusion section that articulates an evidence-based argument to support or refute the claim being investigated. When appropriate it should also include a comparison with the results of other work and/or accepted values.
    m. A references/bibliography section citing other works referred to during the investigation and formatted appropriately.

Rubric

Above Expectations	Meets Expectations	Developing – High	Developing – Low	Insufficient evidence
Report contains all required elements and approaches a professional level.	Report contains all required elements, is well-constructed and written, but does not approach a professional standard.	Report contains all required elements but is not well-constructed and/or well-written.	Report does not contain all required elements. OR All elements are present, but not differentiated	No report submitted OR Report is 'minimal'

Where/when to apply skills assessments

	Courses			Extracurricular (if applicable)	
Skills	**PHYS 4710/4711 (Adv. Lab.)**	**PHYS 4130 (Comp. Phys.)**	**PHYS 4730/4740 (Research)**	**Research Experience**	**Seminar/ Conference**
Written Communication	X	X	X	X	

X = Definite context for assessment
? = Possible context for assessment

Research Skills -Outcomes-v1-2

<u>Research Skills – Draft Student Learning Outcomes</u>

1. Students will be able to plan a research study for which they:
    a. Select a research project that is feasible in terms of both resources needed and timescale.
    b. Conduct a literature search for previous work on their chosen topic.
    c. Make a reasoned claim/prediction for the expected outcome of their study.
    d. Construct a research proposal encompassing all the above.

Rubric

Above Expectations	Meets Expectations	Developing – High	Developing – Low	Insufficient evidence
At least two subskills demonstrated with high degree of competency. Others with reasonable degree of competency.	All subskills demonstrated with reasonable degree of competency.	At least three subskills demonstrated with reasonable degree of competency or higher. Other demonstrated with lower competency or not demonstrated.	At least two subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency or not demonstrated	Only one subskill demonstrated to any standard. OR No subskills demonstrated.

2. Students will be able to conduct a research study in which they:
    a. Identify appropriate techniques, methods, and equipment.
    b. Develop and document an experimental procedure.
    c. Keep a notebook documenting their work.
    d. Analyze data using appropriate software tools and statistical tests.

Rubric

Above Expectations	Meets Expectations	Developing – High	Developing – Low	Insufficient evidence
At least two subskills demonstrated with high degree of competency. Others with reasonable degree of competency.	All subskills demonstrated with reasonable degree of competency.	At least three subskills demonstrated with reasonable degree of competency or higher. Other demonstrated with lower competency or not demonstrated.	At least two subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency or not demonstrated	Only one subskill demonstrated to any standard. OR No subskills demonstrated.

Where/when to apply skills assessments

	Courses			**Extracurricular (if applicable)**	
Skills	**PHYS 4710/4711 (Adv. Lab.)**	**PHYS 4130 (Comp. Phys.)**	**PHYS 4730/4740 (Research)**	**Research Experience**	**Seminar/ Conference**
Research 1	?		X	X	
Research 2	?		X	X	

X = Definite context for assessment
? = Possible context for assessment

Experimental Investigation -Outcomes-v1-2

<u>Experimental Investigation – Draft Student Learning Outcomes</u>

1. Students will be able to conduct and interpret the results of an experimental investigation.
    a. Demonstrate the ability to develop and/or enhance an experimental procedure.
    b. Follow a systematic experimental procedure and record work/measurements in a notebook in a comprehendible format.
    c. Demonstrate an understanding that flexibility in experimental design and procedure may be necessary.
    d. When appropriate, construct graphs to show the relationship between measured or derived quantities, use appropriate fitting techniques to determine a

mathematical relationship between them, and extract derived quantities from such a fit.

e. Appropriately manipulate and interpret uncertainties in measurements, graphical representations, and derived quantities
f. Use the results from an investigation to support or refute a claim about the relationship between measurable quantities or the values of derived quantities.

Rubric

Above Expectations	Meets Expectations	Developing – High	Developing – Low	Insufficient evidence
At least three subskills demonstrated with high degree of competency. Others with reasonable degree of competency.	At least four subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency.	Three subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency. OR Four subskills demonstrated with reasonable degree of competency or higher. Others not demonstrated.	Two subskills demonstrated with reasonable degree of competency or higher. Others demonstrated with lower competency. OR Three subskills demonstrated with reasonable degree of competency or higher. Others not demonstrated.	Two or fewer demonstrated, but not to appropriate standard.

Where/when to apply skills assessments

	Courses			**Extracurricular (if applicable)**	
Skills	**PHYS 4710/4711 (Adv. Lab.)**	**PHYS 4130 (Comp. Phys.)**	**PHYS 4730/4740 (Research)**	**Research Experience**	**Seminar/ Conference**
Experimental Investigation	X	?	X	X	

X = Definite context for assessment
? = Possible context for assessment

Appendix 3: SLO4 Results
Report on Alumni Survey

Report on Alumni Survey - 2018

Introduction

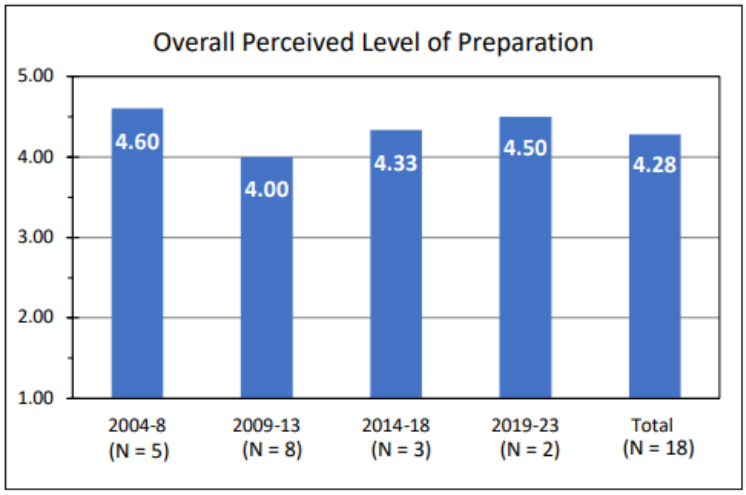
During the fall of 2023, TTU physics alumni were contacted and asked to complete an updated version of online survey we have used in the past which includes six new questions asking them to evaluate our efforts to help them feel connected to other physics students and faculty (hosted by Qualtrics). From this, and previous requests, we now have responses from seventy-four alumni, with graduation years from 1947 to 2023. In order to extract feedback relevant to the current program, we limited analysis to respondents who have graduated since 2000. Of those eighteen respondents, fifteen continued on to graduate school, in either physics (10) or some other field (5), while three immediately entered employment after graduating. In order to determine any recent trends, this group was subdivided into four cohorts: 2004-2008 (N = 5), 2009-2013 (N = 8), 2014-2018 (N = 3) and 2019-2023 (N = 2) graduates. Unfortunately, with only two responses from our most recent cohort, results for this group cannot be considered to be particularly reliable.

Overall Preparation

The first three questions on the survey gathered demographic information. The following questions asked alumni to rate their overall level of preparation, both absolutely and relative to their peers.

How would you rate the overall level of preparation that the TTU physics program provided you toward your next career step?

(1 = Very poor, 2 = Poor, 3 = Adequate, 4 = Good, 5 = Excellent)



The average rating given by all cohorts was between 4.0 and 4.6, indicating that on average our alumni continue to think our program did an excellent job preparing them for their next career step.

(**NOTE**: All comments provided here come from the 2023 survey responses.)

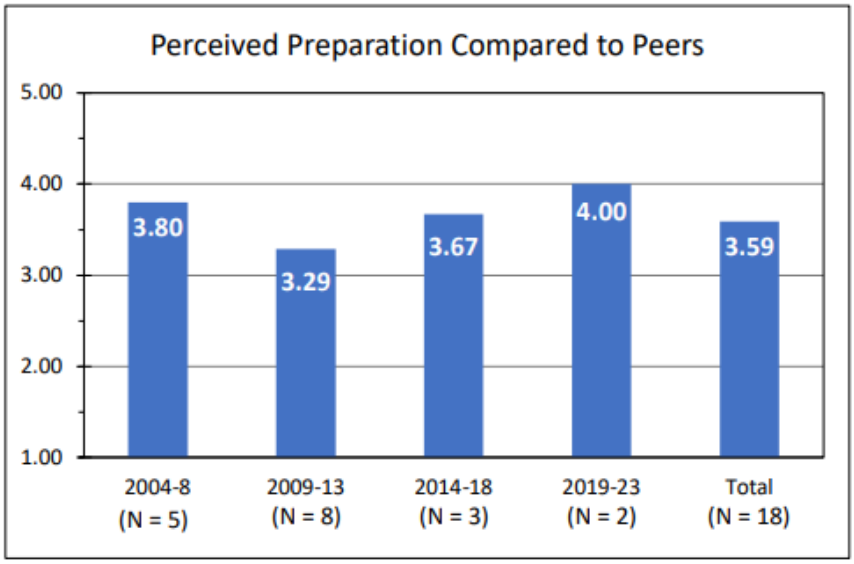
Comments:

My opinion is that the degree at Tennessee Tech provided preparation for graduate school and only graduate school.

Overall I am finding the level of preparation I got compared to my piers is relatively high. However, I know the preparation I got from Dr. Ayik is not going to be sufficient.

When comparing yourself to others following a similar career path, but having graduated from other programs, how would you rate your level of preparation?

(1 = Much Worse, 2 = Worse, 3 = About the same, 4 = Slightly Better, 5 = Much Better)



The average rating showed a dip in 2009-2013 but has recently been showing an upward trend. These results indicate that TTU physics graduates continue to feel that their preparation compares favorably to that of their peers.

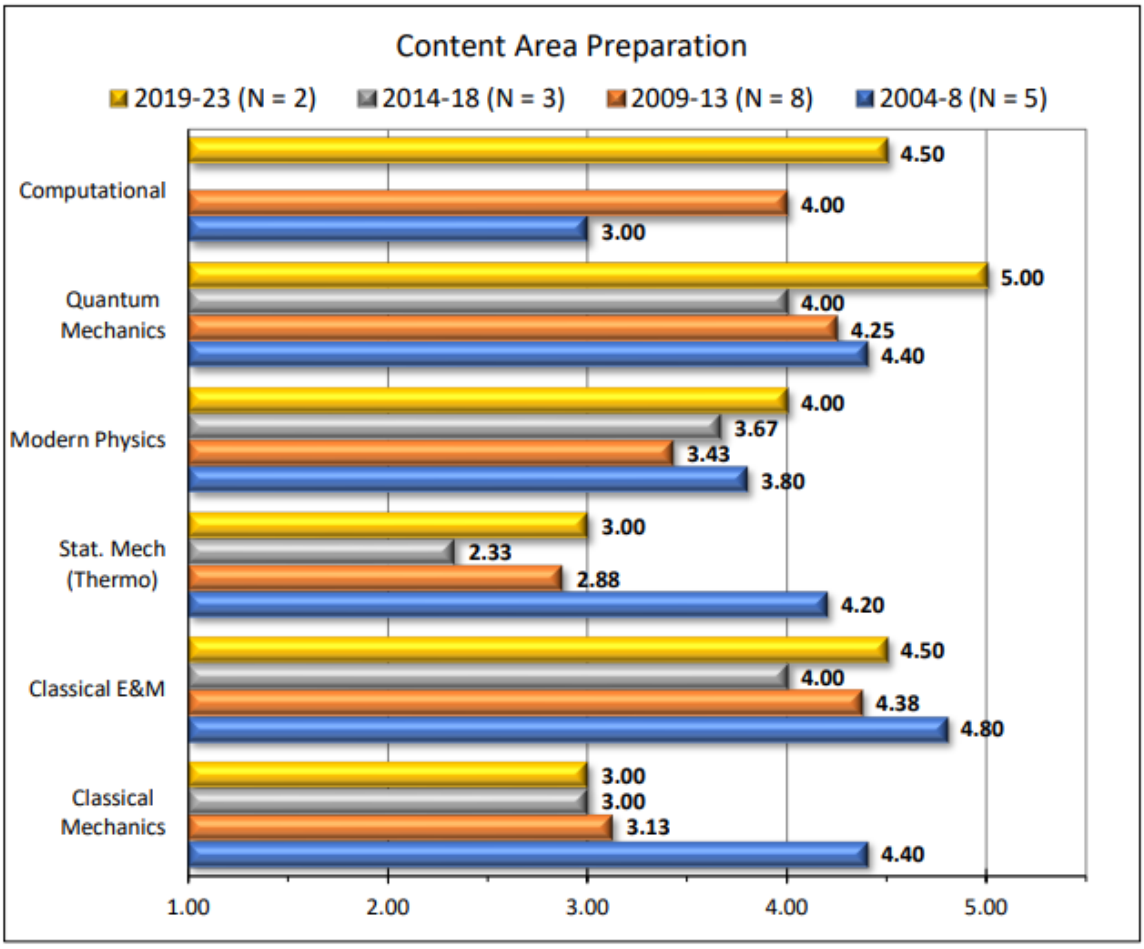
Comments:

I am only in the 1st semester of my 1st year, but at least in quantum 1 I am finding I have seen some things other people have not. It is nothing major, but small things like "oh yeah, how she introduced that concept in class today is how we covered it in undergrad".

Specific Topics

The next question asked for feedback on the level of preparation in specific content areas. The average rating for each cohort is shown below.

(1 = Very poor, 2 = Poor, 3 = Adequate, 4 = Good, 5 = Excellent)



The Computational Physics course (PHYS 4130) was first taught in spring 2015 and only this year appeared on the alumni survey. The responses shown are from the four individuals who responded to this year's alumni survey from cohorts 2004-08 (N = 1), 2009-13 (N = 1) and 2019-2023 (N = 2). While the numbers are small, the trend appears to be positive in response to the department's efforts to address this increasingly important component of the undergraduate curriculum.

Again, this shows that alumni continue to rate their preparation in Electricity and Magnetism and Quantum Mechanics as good to excellent. Statistical and Classical Mechanics have consistently had the lowest perceived levels of preparation with Classical Mechanics dropping to

'Adequate' and Statistical Mechanics dropping below 'Adequate' and approaching 'Poor'. However, these indications should be tempered by the low number of responses from the most recent cohort.

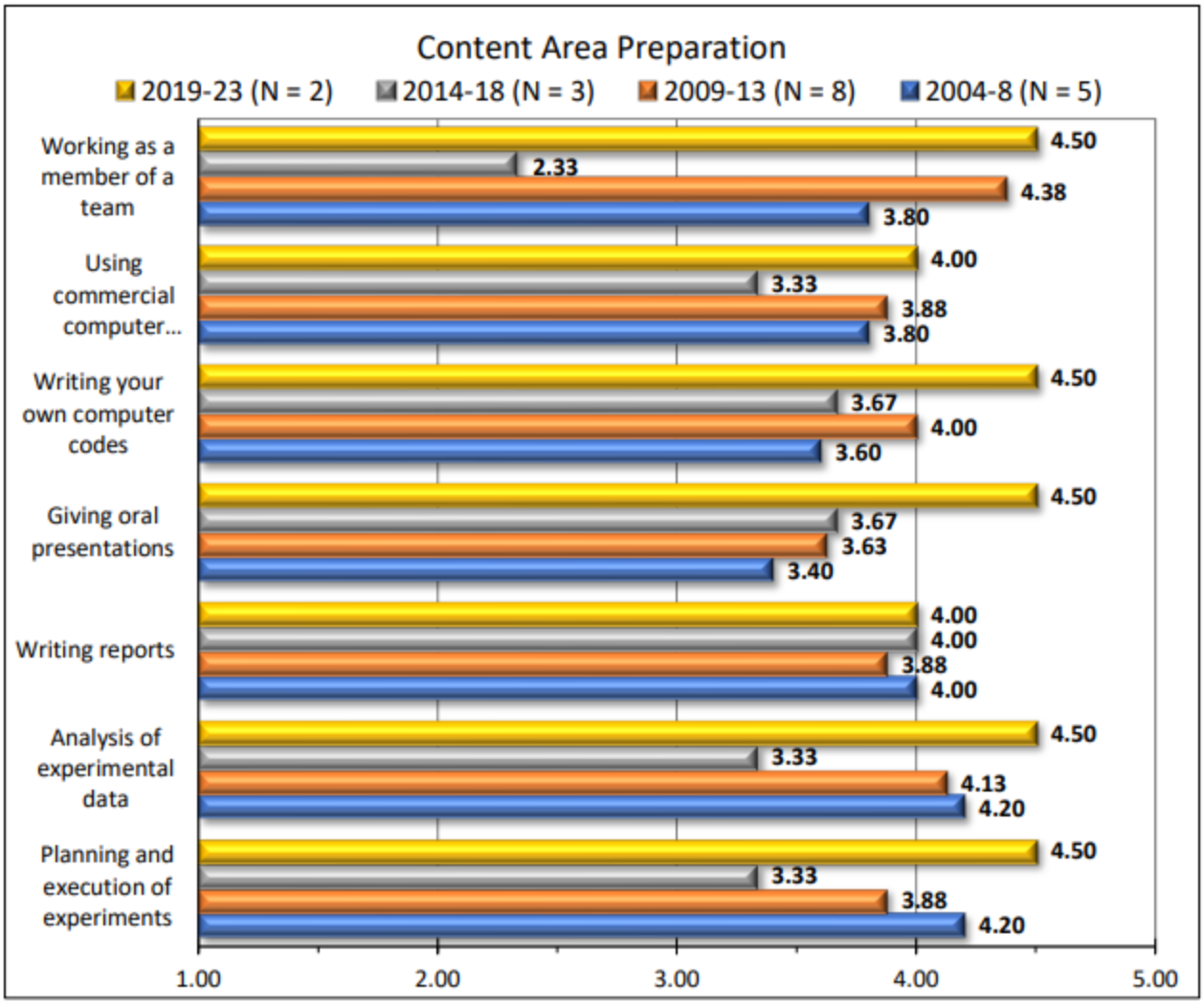
Comments:

again, the only core classes I am taking right now is math methods and quantum 1. I imagine I will have much more to say a year from now.

Specific Skills

Question 7 asked for feedback on the level of preparation in specific skills that we would like our students to acquire. (Working as a member of a team; Using commercial software packages; Writing their own computer code; Making oral presentations; Writing reports; Analyzing experimental data; Planning and executing experiments.) Again, the average rating for each cohort is shown below.

(1 = Very poor, 2 = Poor, 3 = Adequate, 4 = Good, 5 = Excellent)



Comments:

Summer internships were crucial in helping me learn about testing and data analysis

This is a while ago, and I'm not necessarily stating it was the physics programs fault.

I thought advanced lab and the research course were really good for learning these skills. Most definitely keep those. Also the research I did and the presentations I gave based on that were also good.

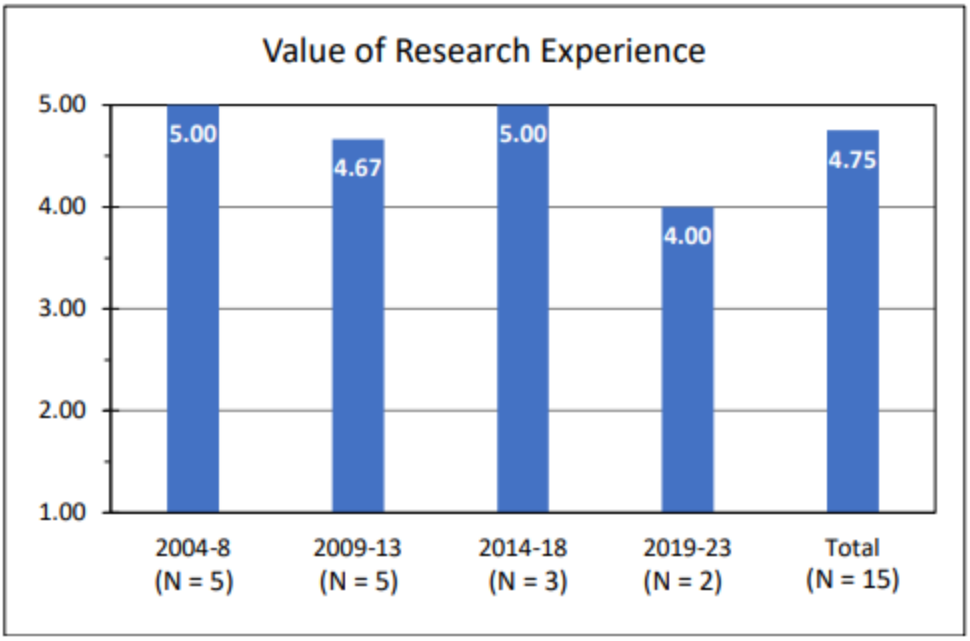
These results indicate that alumni continue to consider the overall level of preparation they received in particular skills to be good. While the 2014-18 cohort, rated working together as a team as low as 2.33, the two responses from the most recent cohort show a much more positive view of this skill as with many of the other skills. This is likely due to the introduction of the research planning and research courses taken in the senior year as well as the various research groups having become more established within the department.

Research Experience

The department has been nationally recognized for its long-standing efforts to involve undergraduates in research. This has been done either by faculty employing students as summer research assistants, or by encouraging them to apply for summer REU programs elsewhere. The value of this effort is evident in the responses to the question:

Please rate how valuable you feel your research experience was in your career preparation.

(1 = Worthless, 3 = Somewhat valuable, 5 = Extremely valuable)



A significant majority of respondents gave their research the highest possible rating giving an overall average of 4.75 out of 5 across all respondents.

Comments accompanying these ratings were all positive.

Comments:

I was fortunate to complete two REU's and I found the social aspect as important as the research. It was valuable to meet with other undergraduate students who were searching for their particular career goals. I still keep in contact with a few friends I made during the summer research experiences

I haven't really done any research yet at my institution so its hard to say how I will feel my undergrad research helped.

Connection to the Department

The last three questions asked for feedback on the department's efforts to help students feel connected to other physics majors and faculty. Unfortunately, we only received feedback from two of our most recent students. Neither of them had taken the PHYS 1137 course so could not provide feedback.

The table below shows the rank in the order of importance the six departmental efforts to help you feel connected to other physics students and faculty. For context, the PHYS 1137 course was first taught in Fall 2018. The Friday afternoon Research Seminars, which are not limited to just physics but include all sciences, began in 2015 and were still relatively new in 2019.

Ranking	2019	2023
1	Friday afternoon Research Seminars	Your research group
2	Physics Club	Physics Lounge
3	Physics Lounge	Friday afternoon Research Seminars
4	Other social events	Other social events
5	Your research group	Physics Club
6	PHYS 1137 Frontiers of Physics course	PHYS 1137 Frontiers of Physics course

Final Comments

Respondents were asked for any final comments about the degree program in general.

I feel strongly that my degree in physics set me up with the best possible foundation for work as an engineer. A good engineer should know from first principles why they are doing something, and physics sets one up for that.