Theory, Computation, Experimentation, and Communication: Moving Towards a Balanced Undergraduate Curriculum

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The Department of Physics at the University of St. Thomas is engaged in an ambitious, collaborative project to effectively embed, computation, experiment, and communication techniques throughout the curriculum.

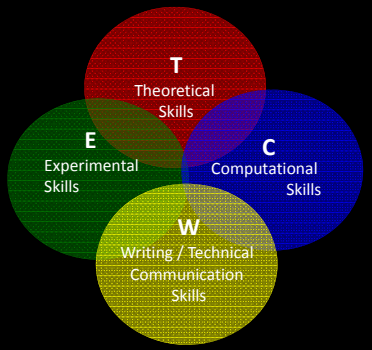
Our sophomore-level modern physics sequence provides an introduction to experimental and computational physics, as well as an introduction to informal and formal technical writing. Computation skills are further refined in a new sophomore level methods of computational physics course.

We moved the advanced laboratory course forward in the curriculum to teach students experimental design and instrumentation skills early so they could put them to good use in other settings. Experimental skills are further developed in optics which includes a rigorous laboratory component. Many lecture-based courses have added short computational projects and / or validation experiments to the semester.

Written and oral communication skills are improved through either papers, laboratory notebooks, poster presentations, or talks.

Through continued exposure, our students learn computation techniques, gain confidence in their experimental skills, and polish their communication skills.

Balancing our curriculum

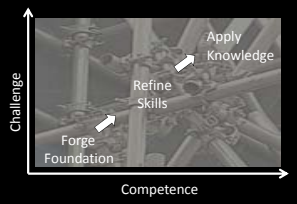


PHYS 410 Stat. Mech. Thermo T{C} w	PHYS 431 Quantum Mechanics T C w {E}			
PHYS 323 Meth. Exp. Physics E C T w	PHYS 325* Meth. Comp. Physics C T w	PHYS 331 Theoretical Mechanics T C w	PHYS 341-2 E & M T c	PHYS 347 Optics T E c w
PHYS 215 Foundations of Mod. Phys. T E W c	PHYS 225 Applications of Mod. Phys. T C w E			
PHYS 111 Classical Phys. Mechanics T E	PHYS 112 Classical Phys. E&M, Optics T E			

Relative emphasis of theory, computation, experiment, and writing / technical communication within our courses

* new course for Fall 2015
{ } not fully implemented

Scaffolding skills throughout the program



1st Stage - Foundations

✓ Explicit instruction
✓ Collaborative environment
✓ Rigor

Experimentation

- PHYS 215 *Foundations of Modern Physics* (signal conditioning, nuclear instrumentation)
- ENGR 240 *Circuit Analysis* (analog electronics)
- PHYS 323 *Methods of Experimental Physics* (advanced lab at the sophomore level)
  - Course built around a single experimental investigation
  - Topics are driven by questions that arise during the investigation
  - Builds on familiar physical concepts while introducing new mathematics, computer aided DAQ, instrumentation, and data analysis
  - Learn how to communicate, discuss ethics, and develop confidence

Computation

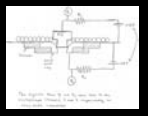
- PHYS 225 *Applications of Modern Physics* (modeling of systems using MATLAB)
  - Required for Physics and Electrical Engineering majors and Physics minors, can be used to satisfy a technical elective requirement
  - Abstract material and sophisticated mathematics
  - Wide range of skills and abilities
  - Understanding of *classical* statistics necessary to understand *quantum* statistics
  - Data analysis: plotting, linearizing, and fitting experimental data
  - Limitations of models – what assumptions did we make?
  - Complex problems – no analytical solution

- PHYS 325 *Methods of Computational Physics* (new course under design at the sophomore / junior level)

2nd Stage Refinement

✓ Students don't know results Instructor does

- PHYS 347 *Optics* (investigation of physical optics – strong laboratory emphasis)
- PHYS 410 *Thermodynamics and Statistical Mechanics* (redesigning current course – strong computation emphasis)
- Laboratory & Computational Homework (built into traditional courses PHYS 331 *Theoretical Mechanics*, 341 *E & M*, and 431 *Quantum*)
  - Connect abstract theory with tangible results
  - Reveal student misconceptions
  - Provide structured opportunities for students to apply their knowledge – practice and repetition
  - Involved but not onerous
  - Low stake problems



3rd stage – Application

✓ Real investigations

- Transitional Undergraduate Research (Research coming out of earlier coursework)
  - Polarization and Insects (PHYS 347)
  - Nonlinear Systems (PHYS 323)
  - Searching for Exoplanets (PHYS 325)
- Traditional Undergraduate Research
- REU's / Internships
- ENGR 380/381 – Senior Design

A. Green, P. Ohmann, N. Leininger,* J. Kavanaugh* *Physics Teacher*, Vol. 48, No 1

V. Tran*, E. Brost*, M. E. Johnston, J. A. Jalkio, *Chem.*, **23**, June 2015, 033103

Key components in rebalancing our program

Structural

- Explicitly focusing on computation
- Moving advanced lab forward in the curriculum
- Adding laboratory and computational homework
- Tying student's course preparation into research through Transitional Undergraduate Research

Cultural

- It is NOT a solo effort
  - everyone was involved
  - department wide commitment key to long-term viability
- Ideas evolve

  Grant writing helped significantly to refine our thinking

  NSF CCLI and TUES grants (5 curriculum grants from 5 different faculty)
  MN SPACEGRANT
  MathWorks curriculum development grant
- We will never be done – and that's ok

http://www.stthomas.edu/physics/research/Curriculum