Assessing Undergraduate Physics Program Learning Objectives at UC Merced

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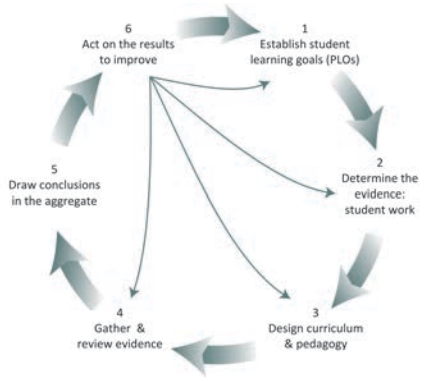


The Assessment Cycle: Hybrid of Suskie, CIRTL Network, Wiggins & McTighe

Stage 1: Establish student learning goals.

Program Learning Objectives (PLOs)

1. **Physical Principles.** Students will be able to apply basic physical principles—including classical mechanics, electricity and magnetism, quantum mechanics, and thermal physics—to explain, analyze, and predict a variety of natural phenomena.
2. **Mathematical Expertise.** Students will be able to translate physical concepts into mathematical language. Furthermore students will be able to apply advanced mathematical techniques (e.g., calculus, linear algebra, probability, and statistics) in their explanations, analyses, and predictions of physical phenomena.
3. **Experimental Techniques.** Students will be able to take physical measurements in an experimental laboratory setting and analyze these results to draw conclusions about the physical system under investigation, including whether their data supports or refutes a given physical model.
4. **Communication and Teamwork Skills.** Students will be able to clearly explain their mathematical and physical reasoning, both orally and in writing, and will be able to communicate and work effectively in groups on a common project.
5. **Research Proficiency.** Students will be able to formulate personal research questions that expand their knowledge of physics. Students will be able to apply sound scientific research methods to address these questions, either by researching the current literature or developing independent results.

Stage 2: Determine the evidence: student work.
Stage 3: Design curriculum & pedagogy.

Curriculum Matrix: Maps skills development for core major courses. Signature assignments allow for consistency of assessment evidence *and* flexibility for various faculty teaching styles. Campus support is utilized for indirect evidence.

I = Introduced, R = Reinforced, M = Mastery, A = Assessment Evidence
PLO 4: W = Written communication, O = Oral communication, T = Teamwork

Year	Course Title	Program Learning Objectives					Signature Assignment or Indirect Evidence Support
		1	2	3	4	5	
		Physical Principles	Mathematical Expertise	Experimental Techniques	Communication & Teamwork	Research Proficiency	
1	Introductory I	I	I	I	W, T: I	I	
1	Introductory II	I	I	I	W, T: I	I	
2	Introductory III	I	I	R	W, T: R	R	
2	Classical Mechanics	R	R, A		W: R, A O: I	R, A	PLO 2: Final exam: quantitative question PLO 4, 5: Literature review/presentation
2 – 3	Thermodynamics	R, A	R				PLO 1: Final exam: conceptual question
3 – 4	Electrodynamics	R	R, A				PLO2: Final exam: quantitative question
3 – 4	Modern Physics Lab	R		R, A	W, O, T: R	R	PLO 3: Technical report
3 – 4	Quantum Mechanics	R, A	R/M		O, T: R, A	R	PLO 1: Final exam: conceptual question PLO 4: Group video
4	Senior Research	M	M	(M, A)	(T: M)	(M, A)	PLO 3, 5: Advisor feedback
4	Senior Thesis	M, A	M, A	M, A	W, O: M, A	M, A	Senior Thesis & Presentation
All	Indirect Evidence: Focus Groups/Surveys	A	A	A	A	A	Campus: Center for Research on Teaching Excellence
After	Indirect Evidence: Senior Exit Survey	A	A	A	A	A	Campus: Institutional Planning & Analysis

Stage 4: Gather & review evidence.

Indirect Evidence: *Asks students' opinions* about their achievements of the PLOs, what aspects of the program helped them achieve the PLOs (and why), what actions the program may take to improve their learning. (Walvoord)

Senior Exit Survey question. Please rate yourself on the skills and knowledge in the following statements. Please give yourself two different scores, one score for when you started studying at UC Merced, and a second score for today.

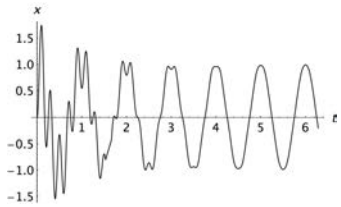
You can analyze experimental results to draw conclusions about the physical system under investigation, including whether the data supports or refutes a given physical model.

Highly proficient | Moderately proficient | Barely proficient | Not proficient

Stage 4: Gather & review evidence.
Stage 5: Draw conclusions in the aggregate.

Direct Evidence : A sample of student work completed at or near the end of their course of study, *analyzed by faculty to find the strengths and weaknesses of the students as a group*. (Walvoord)

Conceptual final exam question for PLO 1: Physical Principles.
From Classical Mechanics final exam. Determine everything possible about this one-dimensional system.



		Reviewer A		
		E	A	U
Reviewer B	E	6	1	0
	A	2	15	3
	U	0	1	6

Joint distribution matrix

Rubric: Take the conditions of the exam—timed/take home, open/closed book, etc.—into account when applying this rubric.

Unacceptable (U)	Acceptable (A)	Excellent (E)

• Knowledge of basic physical principles is missing.
• Knowledge of basic physical principles is evident, but
  • Application is missing.
  • Significant errors exist in their application.
  • *Example: Student can write down Maxwell's equations, but cannot determine magnetic field around a wire.*
• Knowledge and/or application of two or more physical principles are confused.
	• Knowledge of basic physical principles is evident.
	• Those principles are applied correctly,
	  • although *some* errors exist.
	• Misconception in knowledge or application of more subtle feature(s) of principle may exist.
		• Knowledge of basic physical principles is evident.
		• Those principles are applied correctly,
		  • although *minimal* errors may be present.
		• Evidence that more subtle aspects of physical principles are known and correctly applied.

Stage 6: Act on the results to improve.

Physics Program

- **Mathematical Physics Course:** New elective supported by direct evidence and student focus group (PLO 2).
- **Quantitative vs. Qualitative:** Mathematically-focused questions often disguised students' challenges with conceptual material. Increased faculty awareness leads to richer assignments and exams (PLOs 1 and 2).
- **Introductory Physics III Labs:** Increased emphasis on data reduction & analysis (PLO 3).
- **Quantum Video Project:** Video must be correct, engaging, and suitable for freshman seminar students (PLO 4). Students work in teams (PLO 4).
- **Literature Review in Introductory Courses:** and writing assignments in upper-division courses increases students' ability to work with literature and communicate in written form (PLOs 4 and 5).
- **Senior Thesis Presentations:** Sharing rubric with students results in higher quality presentations (PLOs 4 and 5).

Assessment Practices

- **Stage 1**: Learning goals
  - Unspecified context for research proficiency (PLO 5) and varied lengths of students' research experiences led to difficulties in using senior research performance for PLO assessment.
  - Each course syllabus specifies relationship between course learning objectives (CLOs) to PLOs.
- **Stage 2**: Determine evidence
  - The Curriculum Matrix
    - The curriculum matrix identified gaps in developing experimental techniques.
    - Evidence is consistently collected and spread out over all required semester-long courses.
  - Indirect evidence
    - Using discussion sections allows for high participation rates for surveys and focus groups.
- **Stage 3**: Design curriculum & pedagogy
  - Faculty choose the final exam problem pertinent to their own course, which accommodates various teaching styles.
- **Stage 4**: Gather & review evidence
  - Descriptive rubrics leads to better inter-rater reliability.
  - Rubrics can be applicable to course- *and* program-level assessment. Overall score for course, rubric details for program.
  - Useful rubric resources:
    - *Walvoord*: Descriptions & Examples.
    - *AAC&U Value Rubrics*: Vetted descriptive rubrics, adaptable. (PLOs 2, 4)
    - *Willison*: Research Skills, applicable to undergraduate research, but requires faculty agreement on scaling for different student experience levels. (PLO 5)
  - Quality of student writing can affect assessment of non-communication PLOs. (PLOs 1, 3, 5)

References

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4. B. E. Walvoord, *Assessment Clear & Simple, 2nd ed.* (Jossey-Bass, San Francisco, CA 2010).
5. VALUE Rubrics. *Assessing Outcomes & Improving Achievement: Tips & Tools for Using Rubrics*, T. L. Rhodes ed., Association of American Colleges & Universities, 2010.
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