ASSESSING UNDERGRADUATE PHYSICS PROGRAM LEARNING OBJECTIVES

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ABSTRACT

- Establishing and assessing program learning objectives (PLOs) provides a research-based method to improve our undergraduate physics education at UC Merced. We have five PLOs: (1) physical principles, (2) mathematical expertise, (3) experimental techniques, (4) communication and teamwork, and (5) research proficiency. We use a six-stage assessment cycle for each PLO that either validates current practice or drives needed modifications to our assessment process and/or program. Our curriculum matrix elucidates skills development and applicable evidence. Although we collect evidence for each PLO annually, we focus on one PLO each year and have just finished our first assessment of each. Our approach strives to maximize the ease and applicability of our assessment practices while maintaining faculty's flexibility in course design & delivery.

OUTLINE

- Assessment at UC Merced
- Assessment Cycle
  - Program Learning Objectives (PLOs)
  - Curriculum Matrix
  - Descriptive Rubrics
- Challenges & Possibilities
- References & Additional Resources

ASSESSMENT AT UC MERCED

- Campus Level
  - Coordinator for Institutional Assessment & Accreditation Liaison Officer
- School Level
  - Assessment Manager
- Program Level
  - Faculty Assessment Organizers
- Course Level
  - Syllabi

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USE OF ANNUAL PLO ASSESSMENT REPORTS

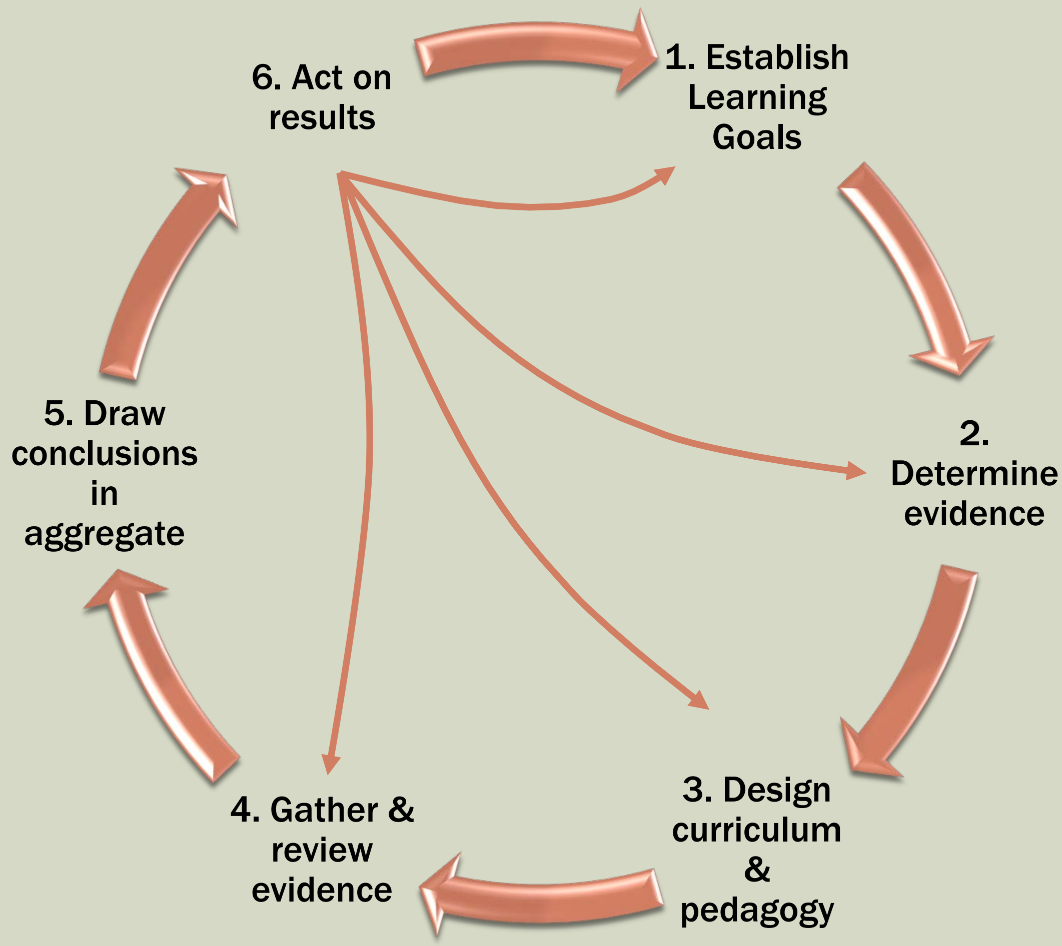
- Program Level
  - Documentation of data-driven changes
  - Basis for program review reports
  - Proven background in assessment for training grant proposals
- School Level Assessments
- Campus Level
  - Combined with other programs' PLO reports: documents need for campus-level resources
    - Writing Task Force
  - Accreditation & Reaccreditation
    - Identify overlap between PLOs and WASC Core Competencies
      - Written communication
      - Oral communication
      - Quantitative reasoning
      - Information literacy
      - Critical thinking

ASSESSMENT & ACCREDITATION

- Initial Accreditation in July 2011
  - Western Association of Colleges & Schools (WASC)

- One of three recipients of the **2012 Award for Outstanding Institutional Practice in Student Learning Outcomes** by the Council for Higher Education Accreditation (CHEA)
  1. Articulation & evidence of outcomes
  2. Success with regard to outcomes
  3. Information to public about outcomes
  4. Use of outcomes for educational improvement

ASSESSMENT CYCLE



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

STAGE 1: PROGRAM LEARNING OBJECTIVES (PLOs)

1. Physical Principles
2. Mathematical Expertise
3. Experimental Technique
4. Communication & Teamwork
5. Research Proficiency

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STAGE 1:
PROGRAM LEARNING OBJECTIVES (PLOS)

- Physical Principles. Students will be able to apply basic physical principles—including classical mechanics, electricity and magnetism, quantum mechanics, and statistical mechanics—to explain, analyze, and predict a variety of natural phenomena.
- 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.
- 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.
- 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.
- 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.

STAGES 2 & 3: CURRICULUM MATRIX

Course Title	Program Learning Objectives					Evidence
	1 Physical Principles	2 Mathematical Expertise	3 Experimental Techniques	4 Communication & Teamwork	5 Research Proficiency	
Introductory I & II	I	I	I	I	I	
Introductory III	I	I	R	I/R	R	
Classical Mechanics	R	R		I/R	R	PLO 2: Final exam: quantitative question PLO 4, 5: Literature review/presentation
Thermodynamics	R	R				PLO 1: Final exam: conceptual question
Electrodynamics	R	R/M				PLO2: Final exam: quantitative question
Modern Physics Lab	R		R/M	R	R	PLO 3: Technical report
Quantum Mechanics	R	R/M		R	R	PLO 1: Final exam: conceptual question PLO 4: Group video
Senior Research & Thesis	M	M	(M)	M	M	Senior Thesis & Presentation
Campus resources						**Indirect Evidence** **Surveys & Focus Groups**

I = Introduce R = Reinforce M = Mastery

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CURRICULUM MATRIX: CREATING

- Cross-references core courses & PLOs
  - Courses in roughly chronological order to map skills progression
  - Refer to course syllabi and instructors to determine level of emphasis (Introduce, Reinforce, or Mastery)
- Evidence
  - From course syllabi and instructors, identify direct evidence (i.e. student work) to collect.
  - Identify campus resources and convenient options (i.e. discussion sessions) to collect indirect evidence (i.e. student opinions of their skills).
- Review & Refine Matrix
  - Do all core courses contribute to PLO development?
  - Are there adequate opportunities for skills reinforcement for each PLO?
- Utilize Curriculum Matrix
  - Faculty Assessment Organizer (FAO) or designated person reminds instructors of evidence to be collected (i.e. purely conceptual question on final exam for PLO 1).
  - Collect data every term, every year

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CURRICULUM MATRIX: GUIDELINES & OPTIONS

- For overall program assessment and accreditation purposes, evidence should reflect students' abilities at or as close to graduation as possible.
  - Evidence can be collected in earlier stages of program as well. Review if mastery-level assessment shows students are not meeting anticipated standards.
- Work with faculty to agree upon direct evidence such that it is flexible regardless of the instructor.
- Response rates for indirect evidence can be difficult.
  - Utilizing a discussion session time increases participation rates.
  - Utilize campus resources as reasonably possible (i.e. add questions to the senior exit survey)

STAGE 4: RUBRICS

- Limited to context of course level

Criteria	Unacceptable (U)	Acceptable (A)	Excellent (E)
Criteria 1	Descriptions & examples for each rating & criteria		
Criteria 2			

- Applicable across the curriculum

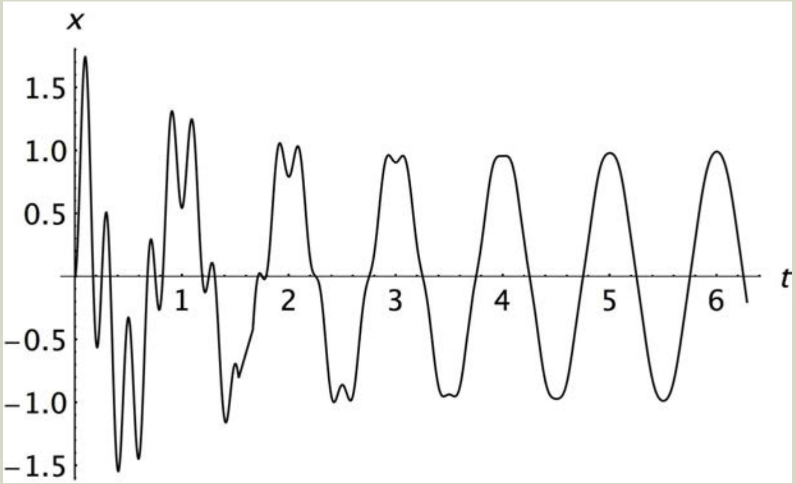
Criteria	Capstone (4)	Milestone (3)	Benchmark (2)	Poor (1)
Criteria 1	Descriptions & examples for each rating & criteria			
Criteria 2				

  - VALUE Rubrics. Assessing Outcomes & Improving Achievement: Tips & Tools for Using Rubrics, T. L. Rhodes ed., Association of American Colleges & Universities, 2010.

STAGE 4:
APPLYING THE RUBRIC

From Classical Mechanics final exam.
(PLO1: Physical Principles)

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				

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STAGE 4: RUBRICS

Physical Principles		
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.
• 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.

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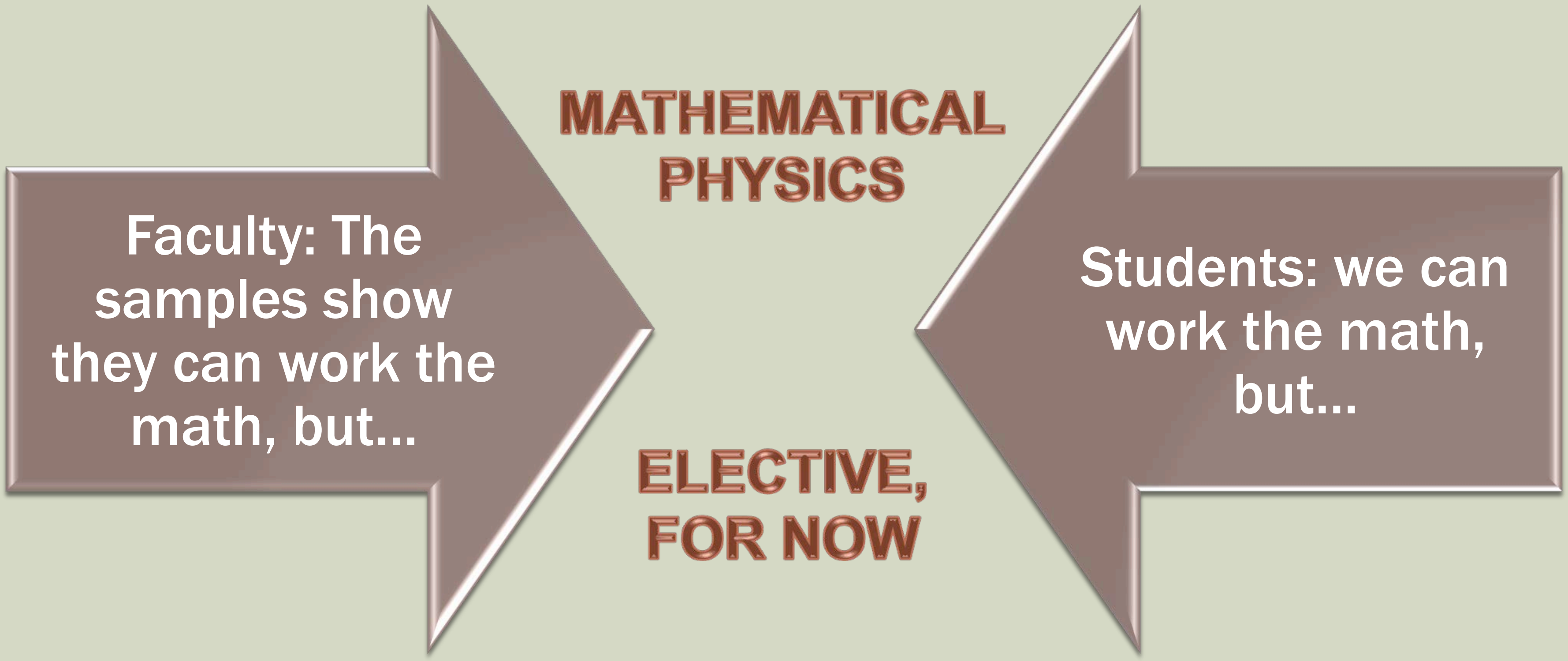
STAGE 4:
INDIRECT EVIDENCE

- Example of campus support: 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.				
Started	Highly proficient	Moderately proficient	Barely proficient	Not proficient
Now	Highly proficient	Moderately proficient	Barely proficient	Not proficient

STAGE 5: DRAW CONCLUSIONS IN THE AGGREGATE

- Mathematical Expertise. Clear conclusions!



STAGE 5:
DRAW CONCLUSIONS IN THE AGGREGATE

- Experimental Techniques. It's not so clear…

Faculty: collecting is fine, analyzing needs more work.

SMALL SAMPLE SIZES

DIFFERENT STUDENTS & QUESTIONS

WRITING QUALITY

Students: 83% of us achieved Experimental Techniques

STAGE 6:
EFFECTS ON 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).

STAGE 6:
EFFECTS ON ASSESSMENT

- Stage 1: Learning goals
  - PLO 5: Research Proficiency. Providing context.
  - Syllabi: PLOs and Course Learning Objectives (CLOs) better aligned
- Stage 2: Determine evidence
  - The Curriculum Matrix
  - Indirect evidence: use discussion sessions to maximize participation
- 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.

CHALLENGES & PROMISING LEADS

Challenges

- Writing & non-communication PLOs
- Same PLO, different final exam question each year

Possibilities

- Grade once, use twice
  - Rubric total = assignment score
  - Rubric details = program assessment data

REFERENCES & RESOURCES

- References

1. L. A. Suskie, Assessing Student Learning: A Common Sense Guide (Jossey-Bass, San Francisco, CA 2009).
2. Center for the Integration of Research, Teaching, and Learning (CIRTL Network), Teaching-as-Research (TAR): Developmental Framework, www.cirtl.net/CoreIdeas/teaching_as_research, 2013.
3. G. Wiggins, J. McTighe, Backward Design in Understanding by Design (Assn. for Supervision & Curriculum Development, Alexandria, 2005).
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.

- Additional Resources

1. J. Willison, K. Regan, The Research Skills Development Framework, www.adelaide.edu.au/rsd/framework, 2006.