ASSESSING UNDERGRADUATE PHYSICS PROGRAM LEARNING OBJECTIVES AT UC MERCED

AAPT 2014 Summer Meeting
University of Minnesota
Minneapolis, MN
July 26 - 30
Establishing and assessing program learning objectives (PLOs) provides a research-based method to improve our undergraduate physics education. 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. 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. A curriculum matrix elucidates skills development and applicable evidence. Descriptive rubrics result in higher inter-rater reliability and, in some cases, can be utilized at the course and program levels. Utilizing existing campus resources, challenges with evidence & rubrics, and strategies for increasing student and faculty participation are also discussed.
OUTLINE

- Humble Beginnings
  - UC Merced
  - Assessment & Accreditation
- Assessment Cycle
  - Program Learning Objectives (PLOs)
  - Curriculum Matrix
  - Descriptive Rubrics
- Challenges & Possibilities
- References & Additional Resources
University of California, Merced
10th campus of the UC system
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
1. Establish Learning Goals
2. Determine evidence
3. Design curriculum & pedagogy
4. Gather & review evidence
5. Draw conclusions in aggregate
6. Act on results

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
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

<table>
<thead>
<tr>
<th>Course Title</th>
<th>Program Learning Objectives</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Physical Principles</td>
<td>Mathematical Expertise</td>
</tr>
<tr>
<td>Introductory I &amp; II</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>Introductory III</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>Classical Mechanics</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Thermodynamics</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Electrodynamics</td>
<td>R</td>
<td>R/M</td>
</tr>
<tr>
<td>Modern Physics Lab</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Quantum Mechanics</td>
<td>R</td>
<td>R/M</td>
</tr>
<tr>
<td>Senior Research &amp; Thesis</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Campus resources</td>
<td></td>
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</tr>
</tbody>
</table>

I = Introduce  
R = Reinforce  
M = Mastery
STAGE 4: RUBRICS

- Limited to context of course level

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Unacceptable (U)</th>
<th>Acceptable (A)</th>
<th>Excellent (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criteria 2</td>
<td>Descriptions &amp; examples for each rating &amp; criteria</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Applicable across the curriculum

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Capstone (4)</th>
<th>Milestone (3)</th>
<th>Benchmark (2)</th>
<th>Poor (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Criteria 2</td>
<td>Descriptions &amp; examples for each rating &amp; criteria</td>
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</tbody>
</table>

### Presentation Rubric (excerpt)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Capstone</th>
<th>Milestone</th>
<th>Benchmark</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation Style</td>
<td>Speaker is clear and confident. Gives a professional impression.</td>
<td>Clear speech, and quickly overcomes occasional lapses in confidence or hesitation.</td>
<td>Somewhat nervous or hesitant style, but gets the message across. Some flaws i.e. avoids eye contact, looking a floor/screen or mumbling.</td>
<td>Very nervous, hesitant or disjointed style, which interferes with ability to communicate information to audience.</td>
</tr>
</tbody>
</table>

### STAGE 4: RUBRICS

#### Physical Principles

<table>
<thead>
<tr>
<th>Unacceptable (U)</th>
<th>Acceptable (A)</th>
<th>Excellent (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Knowledge of basic physical principles is missing.</td>
<td>• Knowledge of basic physical principles is evident.</td>
<td>• Knowledge of basic physical principles is evident.</td>
</tr>
<tr>
<td>• Knowledge of basic physical principles is evident, but</td>
<td>• Those principles are applied correctly,</td>
<td>• Those principles are applied correctly,</td>
</tr>
<tr>
<td>• Application is missing.</td>
<td>• although some errors exist.</td>
<td>• although minimal errors may be present.</td>
</tr>
<tr>
<td>• Significant errors exist in their application.</td>
<td>• Misconception in knowledge or application of more subtle feature(s) of principle may exist.</td>
<td>• Evidence that more subtle aspects of physical principles are known and correctly applied.</td>
</tr>
<tr>
<td>• Knowledge and/or application of two or more physical principles are confused.</td>
<td></td>
<td></td>
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</tbody>
</table>
From Classical Mechanics final exam.

Determine everything possible about this one-dimensional system.

Joint distribution matrix

<table>
<thead>
<tr>
<th></th>
<th>E</th>
<th>A</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E</strong></td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>A</strong></td>
<td>2</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td><strong>U</strong></td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Started</th>
<th>Highly proficient</th>
<th>Moderately proficient</th>
<th>Barely proficient</th>
<th>Not proficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Now</td>
<td>Highly proficient</td>
<td>Moderately proficient</td>
<td>Barely proficient</td>
<td>Not proficient</td>
</tr>
</tbody>
</table>
STAGE 5:
DRAW CONCLUSIONS IN THE AGGREGATE

- Mathematical Expertise. Clear conclusions!

Faculty: The samples show they can work the math, but...

Students: we can work the math, but...

MATHEMATICAL PHYSICS

ELECTIVE, FOR NOW
STAGE 5: DRAW CONCLUSIONS IN THE AGGREGATE

- Experimental Techniques. It's not so clear...

Faculty:
collecting is fine, analyzing needs more work.

Students:
83% of us achieved Experimental Techniques

- SMALL SAMPLE SIZES
- DIFFERENT STUDENTS & QUESTIONS
- WRITING QUALITY
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 1: Learning goals
- 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

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Possibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Writing &amp; non-communication PLOs</td>
<td>- Grade once, use twice</td>
</tr>
<tr>
<td>- Same PLO, different final exam question each year</td>
<td>- Rubric total = assignment score</td>
</tr>
<tr>
<td></td>
<td>- Rubric details = program assessment data</td>
</tr>
</tbody>
</table>
References


Additional Resources