Using an ECR Framework to Characterize Problem Difficulty

Elizabeth Gire
N. Sanjay Rebello

Kansas State University

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Research Questions

How do students’ and instructors’ estimation of difficulty compare?

How does the complexity of a problem affect its perceived difficulty?
Project

- Developed a Survey of Problem Difficulty Estimation (SPDE)
- SPDE → Students & Instructors
- Developed a rubric for textbook style physics problems.
- Correlation between SPDE and the rubric

SPDE (Survey of Problem Difficulty Estimation)

- 16 Work & Mechanical Energy problems
  - Halliday, Resnick & Walker, 7th Ed.
  - Context Rich Problems
  - Numbers, symbols, equations, graphs, pictures
- Online Delivery

<table>
<thead>
<tr>
<th>Rate</th>
<th>Solve &amp; Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Easiest</td>
</tr>
<tr>
<td>10 pt Likert-Scale</td>
<td>Most Difficult</td>
</tr>
<tr>
<td>Question</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16</td>
</tr>
</tbody>
</table>
**SPDE → Students & Instructors**

15 **Freshman Physics Majors**

“Estimate the difficulty”

14 **Instructors**

“Estimate the difficulty for a student”

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**Independent Samples Mann-Whitney U Test**

<table>
<thead>
<tr>
<th>Problem</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
<th>P5</th>
<th>P6</th>
<th>P7</th>
<th>P8</th>
<th>P9</th>
<th>P10</th>
<th>P11</th>
<th>P12</th>
<th>P13</th>
<th>P14</th>
<th>P15</th>
<th>P16</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-value</td>
<td>0.71</td>
<td>0.85</td>
<td>0.96</td>
<td>0.10</td>
<td>0.04</td>
<td>0.44</td>
<td>0.01</td>
<td>0.34</td>
<td>0.79</td>
<td>0.01</td>
<td>0.96</td>
<td>0.00</td>
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</tr>
</tbody>
</table>

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**Rubric - ECR Framework**

**Exposition**

Liz is a post-doc in the Kansas State physics education research group.

**Complication**

The physics education community is unaware of the work that she is doing at Kansas State University.

**Resolution**

Liz goes to the AAPT 2010 Winter Meeting and gives a well-received talk about her research.

Baggett, 1979
ECR & Physics Problems

How much potential energy is stored in a spring with spring constant $k = 170 \text{ N/m}$ when it is compressed 5 cm?

**Exposition**

Spring with $k = 170 \text{ N/m}$ compressed 5 cm

**Complication**

- What physics idea to use?
- Definition of potential energy for linear spring
  
  \[ U = \frac{1}{2}kx^2 \]

**Resolution**

- Which numbers go with which variables?
  
  $k = 170 \text{ N/m}, x = 5 \text{ cm}$

- Value of the potential energy

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Reliability

<table>
<thead>
<tr>
<th>Problems</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solved Textbook Examples</td>
<td>0.78</td>
</tr>
<tr>
<td>SPDE Problems</td>
<td>0.72</td>
</tr>
</tbody>
</table>
ECR & SPDE Correlation

Instructors

Students

Conclusions

- Student and instructor estimation of problem difficulty can be quite different
  - No global trend
  - Context rich problems → students estimate as easier
- Instructors’ difficulty estimations rely more strongly on the number of steps in the solution than do students’.
  - Compare correct response rate with difficulty estimation & ECR score
  - Other physics topics
Thank You

egire@phys.ksu.edu
srebello@phys.ksu.edu

SPDE (Survey of Problem Difficulty Estimation)
- Online survey
- 16 Work & Mechanical Energy problems
  - Halliday, Resnick & Walker, 7th Ed.
  - Context Rich Problems
  - Numerical, equations, graphs, pictures

| Position: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| Winter   | Q2       | Q11      | Q6       | Q7       | Q8       | Q1       | Q9       | Q12      | Q15      | Q3       | Q16      | Q10      | Q13      | Q14      | Q4       | Q5       |
| Spring   | Q3       | Q5       | Q16      | Q7       | Q10      | Q1       | Q11      | Q12      | Q13      | Q4       | Q14      | Q6       | Q8       | Q9       | Q2       | Q15      |
| Summer   | Q13      | Q3       | Q7       | Q4       | Q14      | Q5       | Q10      | Q8       | Q2       | Q12      | Q15      | Q6       | Q11      | Q1       | Q16      | Q3       |
| Fall     | Q11      | Q2       | Q8       | Q5       | Q1       | Q15      | Q6       | Q9       | Q13      | Q14      | Q16      | Q4       | Q7       | Q12      | Q10      | Q3       |

Solve & Rank

Rank 1 → Easiest
10 pt Likert-Scale 10 → Most Difficult
What makes a physics problem difficult?

<table>
<thead>
<tr>
<th>Characteristics of the Problem</th>
<th>Interaction Between Problem &amp; Solver</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Amount of information given in the problem</td>
<td>✓ What knowledge does the solver possess that can be used to solve the problem?</td>
</tr>
<tr>
<td>✓ How information given in the problem</td>
<td>✓ What knowledge does the solver possess that they see as relevant to the problem?</td>
</tr>
<tr>
<td>✓ Amount of math manipulation involved in the solution</td>
<td>✓ How familiar is the context?</td>
</tr>
<tr>
<td>✓ Which physics ideas are involved in the solution</td>
<td></td>
</tr>
</tbody>
</table>