Assessment of Instructional Effectiveness in a Physics Course for Preservice Teachers

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Elementary Teacher Education: An Assessment Agenda

- Pre-course Planning:
  - What are objectives for student learning?
  - How will assessment be carried out?
  - What results are anticipated/desired?

- Post-course Assessment:
  - Compare to “traditional” instruction
    - in courses for elementary teachers *(But are there baseline data?)*
    - in general physics courses
  - Compare to other “reformed” instruction

New Inquiry-Based Elementary Physics Course for Nontechnical Students

- One-semester course, met 5 hours per week in lab -- focused on hands-on activities; no formal lecture.
- Taught at Southeastern Louisiana University for 8 consecutive semesters; average enrollment: 14
- Targeted especially at education majors, i.e., “teachers in training.”
- Heavy emphasis on kinematics and dynamics: velocity, acceleration, relationship between force and motion.
- Strictly inquiry-based learning: targeted concepts are not told to students before they have worked to “discover” them through group activities.

Pedagogical Themes of Inquiry-Based Physics Course

- ***"Active" Learning:*** Hands-on activities keep students engaged in learning process.
- ***Conceptual Conflict and Conceptual Change:*** students make predictions of experimental outcomes they anticipate, then test their predictions.
- ***Building of Mental Models:*** Students create detailed conceptual understanding through extended process of exploration and reflection.

Outline of Instructional Method

- **Pretest:** Assess existing knowledge and evaluate preconceptions.
- **Prediction and Discussion:** Student groups predict outcome of various experiments, and debate their predictions with each other.
- **Experimentation:** Student groups design and implement (with guidance!) methods to test predictions.
- **Analysis and Discussion:** Student groups present results and analysis of their experiments, leading to class-wide discussion and stating of conclusions.
- **Assessment:** Students solve both written and practical problems involving concepts just investigated.

- Sample Pretest Question:

A cart on a low-friction surface is being pulled by a string attached to a spring scale. The velocity is measured as a function of time. The experiment is done twice, and the pulling force is varied so that the spring scale reads 1N and 2N for the two trials. Sketch a velocity-time graph for the two trials, with separate lines for each trial; label the two lines 1N and 2N.

- Sample Class Activity (summary):

Using the photogate timers, measure the velocity as a function of time for the low-friction cart, <u>starting from a resting position</u>, when it is pulled by a constant force on the two-meter track. Use the calibrated spring scale to pull the cart with a constant force of 0.20 newtons. Pull the cart for at least five different distances, and find the cart's velocity when it reaches those distances by measuring the time it takes to move a distance equal to the thickness of a pencil. Use the data to plot a graph of the cart's velocity as a function of time. Repeat these measurements for a force of 0.10 newtons. Plot the results from these measurements on the same graph (use different colored pencils or different types of fitting lines).

Among the materials utilized (at one time or another):

- Work sheets and homework sheets from **Tools for Scientific Thinking** (Thornton and Sokoloff)
- Worksheets from **Physics: A Contemporary Perspective (Workbook Vol. 1)** (Knight)
- Original materials developed by Meltzer and Manivannan

What were the goals of instruction?

- Improve students’ conceptual understanding of force and motion, energy, and other topics
- Develop students’ ability to systematically plan, carry out and analyze scientific investigations
- Increase students’ enjoyment and enthusiasm for learning and teaching physics

How well did we achieve our goals?

- For the most part, good student enthusiasm and enjoyment as documented by comments on anonymous questionnaires;
- Noticeable improvements in students' ability to plan and carry out investigations;
- Good conceptual learning on some topics (e.g., kinematics), but …
- ***Poor learning gains for most students on key concepts in force and motion!***

Student Response

At first, most students were <u>required</u> to take course as part of their curriculum . . . Student response was mostly neutral, or negative.

Recently, most students enrolled were education majors, taking course as elective . . . Student response has become <u>very positive</u>.

Anonymous quotes from Fall 1997 evaluations:

- “The atmosphere is very laid back and happy. Great class. I loved it.”
- “ I feel I learned a lot about physics. I had ***<u>never</u>*** had any type of physics until now!! Thanks!!!”
- “I enjoyed the class. I am glad that I took it. I can now say that I successfully finished a physics class.”
- “Physics was made interesting and put on a level that could be understood.”
- “I enjoyed the activities . . . I liked finding out our own answers.”
- “I really enjoyed this class. I have found many activities I can use when I begin teaching.”

Overall Impact of New Elementary Physics Course

What's the bottom line for the students?

They:

- *Gain practice and experience with scientific investigation;*
- *Improve reasoning abilities;*
- *Improve graphing and other technical skills;*
- *Learn physics concepts;*

But:

- *Only a small minority master force & motion concepts;*
- *A significant minority fully retain fundamental misconceptions.*

Assessment of Learning Outcomes

Can students apply knowledge in a context <u>different</u> from that in which it was learned?

- **<u>Change the Context:</u>** use problem types ***different*** from those that have been practiced.
- **<u>Vary the Form of Representation:</u>** not just “word” problems, but also graphical, pictorial, diagrammatic, mathematical, etc.
- **<u>Not just “Paper and Pencil”:</u>** Examine how effectively students apply conceptual knowledge to ***practical*** tasks using ***real*** equipment.

How did we test whether goals were achieved?

- Extensive pre- and post-testing using standard written conceptual diagnostic test items
- Intensive formative assessment: group quizzes and presentations every week
- Continuous evaluation of students' written and verbal explanations of their thinking
- Individual post-instruction interviews with students to probe understanding in depth

Caution: Careful probing needed!

- It is ***very easy*** to overestimate students' level of understanding.
- Students ***frequently*** give correct responses based on incorrect reasoning.
- Students' written explanations of their reasoning are powerful diagnostic tools.
- Interviews with students tend to be profoundly revealing … and extremely surprising (and disappointing!) to instructors.

The Key to In-Depth Assessment: ***Listen*** to the Students!

Individual post-instruction interviews with students revealed:

- extensive confusion on fundamental concepts;
- key misconceptions fully or partially *unresolved*;
- evidence of persistent instructor/student miscommunication;
- validation of evidence from paper-and-pencil assessments regarding poor learning gains.

Summary of Data Analysis

- $\approx$ 25% of students master force/motion relationship.
- $\approx$ 25% of students fail to grasp distinction between velocity and acceleration, or any notion of force/motion relation.
- $\approx$ 50% of students gain inconsistent understanding of force and motion concepts.

Specific Learning Outcomes: ***Kinematics*** (velocity & acceleration)

- Learning gains in kinematics were generally good, particularly for velocity-distance-time relationships.
  - 60-90% correct on graphical questions
- Significant conceptual difficulties with *acceleration* persist.
  - Approximately 25% of students fail to grasp distinction between velocity and acceleration

Specific Learning Outcomes: ***Dynamics*** (Newton's 1st & 2nd laws)

- Overall, fewer than 50% correct responses on ***non-graphical*** questions.
- ***More than*** 50% correct responses on graphical questions (since adopting high-tech computer graphing tools)
- ***Fewer than 25%*** of students *consistently* give correct responses on dynamics questions.
- ***<u>Much lower</u> learning gains*** than reported in university or high-school general physics courses.

Summary

- Intensive inquiry-based physics courses may be an enjoyable and rewarding experience for preservice teachers.
- Effective learning of new physics concepts -- and "unlearning" of misconceptions -- is ***extremely time intensive.***
- Even with great expenditure of time and effort, it may not be possible to communicate certain fundamental physical concepts to ***majority*** of elementary education majors.
- ***Painstaking and exacting assessment of learning outcomes is <u>essential</u> for realistic appraisal of innovative teaching methods.***