TRANSFER OF LEARNING
from College Calculus to
Physics Courses

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Motivation

- Students need to apply what they have learned in one class to another class.

- Students must *be prepared* to apply what they have learned in school to the real world.
Transfer of Learning

Transfer is often defined as the ability to apply what has been learned in one context to a new context\(^1\)

Methods to assess transfer

- One-shot assessments such as performance on tests and examinations
- Graduated prompting\(^2\)

\(^1\)Byrnes (1996) \quad \(^2\)Newmann (1989)
Research Questions

- To what extent do students retain and transfer their calculus knowledge when solving problems in introductory physics?

- What difficulties pertaining to the transfer of calculus do students have while solving these problems?

- What strategies may help students overcome these difficulties?
Phase I: Fall 2004
Individual Think Aloud Interview

- Participants
  - 8 students, volunteer, male
  - Most second year in college
  - Major in Mechanical Engineering
- Video-taped
- Two sessions
- For each session:
  - About one hour long
  - Solve two physics problems
  - Solve isomorphic calculus problems
  - General questions about calculus background and application of their calculus knowledge in physics

1) Electric field caused by a half-circle charge distribution
2) Electric potential caused by changing Electric field
3) Magnetic field caused by a non-constant current distribution
4) Induced current caused by moving of the loop in a changing magnetic field
Results: Phase I

- Self-confidence in calculus knowledge retention
- Realization that calculus is required in physics
- Is the knowledge learned in calculus class enough for physics?
  - Yes (7 of 8)
  - No (1 of 8)
Results: Phase I

- Lack of confidence in setting-up physics problems

Role of calculus?

- Added question: Without calculus knowledge, is it possible to set up the physics problem?
  - Yes (2 of 5)
  - Do not know (1 of 5)
  - No (2 of 5)

Students' self-reflections are consistent with our observations.

- "I am not confident if I set up the problem right or wrong…" "so many numbers and constants to taking account, I get confused, I lose objective of what I am actually looking for…" "as soon as I set it up, there is no problem"

- "formula are all involved calculus, if I do not know, I will not understand the meaning of physics at all…"
Phase II: Spring 2005
Individual Think Aloud Interview

- Participants
  - Five males, three females
  - Various majors

- For each session (two sessions total):
  - Similar format as Phase I
  - Do not solve pure calculus problem
  - Contrast use of “integration” vs. “summation”

Focus on exploring the origin of difficulties
Results: Phase II

- Consistent with results

When to use integration in physics problems

- When problems were similar to the examples they had seen in the text (4 out of 7 interviewees)
  - Could not explain why use integration
  - Could not solve the contrasting cases

- Use integration in terms of adding up the infinitesimally small elements (3 out of 7 interviewees)

"Because it is the example in the book... I do not know the reason"; "I just know there is integral involved, I do not know why"

"...you can not add up an infinite number... then I used integrate"
Results: Phase II

- **Difficulties when applying integrals**
  - Determining the variable of integration
  - Deciding the limits of integration
    - Students usually did not realize they used the wrong limits
  - Origin of difficulties
    - Physics class (majority)
    - Calculus class

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“I know how to integrate it, but it is just figuring out what to integrate, that is the hard part...”

“These are all constants, I do not know what they do if I do not know what they are!”

“...not really to do with my math class.... I know how to integrate it, but it is just figuring out what to integrate, that is the hard part”

I understand them well. ...well, it is not physics is that hard, math is that hard, it is putting them together is hard, it is writing a equation for what I understanding is hard.”
Results: Phase II

- Students prefer to use pre-derived algebraic relationship over calculus relationship.
  - unaware of when to use integration

\[ B = \frac{\mu_0 i}{2\pi r} \quad \text{or} \quad \int \vec{B} \cdot d\vec{s} = \mu_0 i_{\text{enclosed}} \]

- Is use of calculus in physics just “plug and chug”?  
  - Yes (6 of 8)  
  - No (2 of 8)

- "more confidently use algebra expression to go straight rather than understand this (calculus)"
- "I do not need to understand it, just how to do it. And I was doing good this way in calculus"
- "I have to understand or I will be confused"
Students suggestions:

- Learning how to set-up physics problems
- Focus on understanding
- More ‘word’ problems in calculus
- Course sequencing

“...in word problems, you need to think about what integral to set up, so they can do that in calculus, that would be helpful, so when you go to physics, you are learning new material, like electricity, but you already know calculus.”

“I do not think they need to go through all the integration steps, but they need to show how to set it up, show the different varieties...”

“even in calculus, I had to understand why the differentiation of $s^2$ equal to $2s$...”; “why integration and differentiation works.”
Conclusions (1 of 2)

Q1: To what extent do students retain and transfer their calculus knowledge while solving problem in introductory physics?

Students believed that they...
- Retained their calculus knowledge well
- Were able to transfer their knowledge from calculus to physics

Q2: What difficulties pertaining to the transfer of calculus do students have while problem solving?

- Determining whether calculus is applicable in a given physics problem
- Deciding the appropriate variable and limits of integration
- Using oversimplified algebraic relationships to avoid using calculus
Conclusions (2 of 2)

Q3: What strategies may help students overcome these difficulties?

- Better scaffolding to help solve physics problems
- Focus on conceptual understanding
- More application-oriented problems in their calculus course
- More careful attention to course sequencing
Future Plans

- Develop instructional strategies to facilitate students’ transfer from calculus to physics.

- Investigate transfer across other domains e.g.,
  - Physics to Engineering
  - Other disciplines

Are issues similar or different?
Thank You!

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