Assessing College Students' Retention and Transfer from Calculus to Physics

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Research Question

- 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?

Transfer

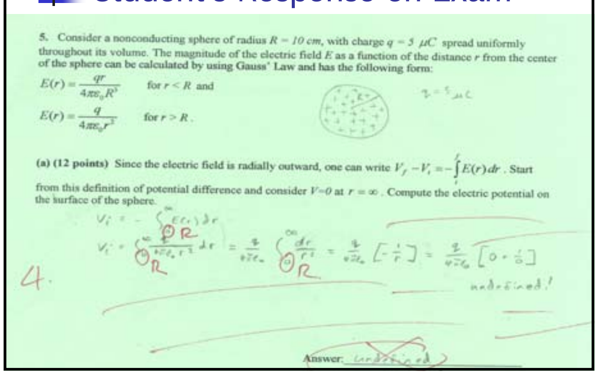
- Transfer is often defined as the ability to apply what has been learned in one context to a new context[1]
- Methods to assess transfer
  - One-shot assessments such as performance on tests and examinations
  - Graduated prompting[2]

[1]Byrnes (1996) [2]Newmann (1989)

Quantitative Method: Examine Students' Exam Performance

- Engineering Physics II students
  - n=147 for Fall 2004, n=269 for Spring 2005
  - Three exams were collected for each semester
- Develop individual rubric to measure *physics correct* and *calculus correct* in every calculus-based physics problem
- Calculate the *Pearson Correlation* between students' calculus and physics performance

Example Student's Response on Exam


5. Consider a nonconducting sphere of radius $R = 10\ cm$, with charge $q = 5\ \mu C$ spread uniformly throughout its volume. The magnitude of the electric field E as a function of the distance r from the center of the sphere can be calculated by using Gauss' Law and has the following form:

$E(r) = \frac{qr}{4\pi\varepsilon_0 R^3}$ for $r < R$ and

$E(r) = \frac{q}{4\pi\varepsilon_0 r^2}$ for $r > R$.

(a) (12 points) Since the electric field is radially outward, one can write $V_f - V_i = -\int_i^f E(r)dr$. Start from this definition of potential difference and consider $V=0$ at $r = \infty$. Compute the electric potential on the surface of the sphere.

Answer:

Example—Scoring Rubric

Points	Physics Performance Criteria	Calculus Performance Criteria
3	Understand need to integrate from infinity to R with the proper E	Do the integration correctly, knowing how to apply the limit
2	Do the integral with the proper E, but do not know what is the limit; wrong with the negative sign; did not put the number in finally	Do the indefinite integration correctly, do not know how to apply limit; algebra wrong: do not provide the numerical answer
1	No integral, Use other formula like V=E*d, or put into the wrong E; or adding two parts	The indefinite integration is not exactly right, some constant is wrong
0	Wrong. Like Use a point charge formula instead of using E	Wrong

Interview—Fall 2004

- Engineering Physics-II students
  - Eight male volunteers
  - Sophomores
  - Mech. Engr. majors
- 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) E field caused by a half-circle charge distribution
2) Electric potential caused by changing E field
3) B field caused by a non-constant current distribution
4) Induced current caused by moving of the loop in a changing magnetic field

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Interview—Fall 2004

- Engineering Physics-II students
  - Five male, three female, various majors
- For each session (two sessions total):
  - Similar format as Fall 2004
  - Do not solve pure calculus problem
  - Solve sets of variation of physics problem to explore the criteria use "integration" instead of "summation"

Focus on exploring the origin of difficulties

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Quantitative Results

Pearson Correlation between Calculus and Physics Performance				
Fall 2004 (n=147) *r>**0.18** indicates strong correlation	Exam 2	Math in part (a)	Physics in part (a)	**0.42**
		Math in part (b)	Physics in part (b)	**0.36**
	Exam 4	Math in part (a)	Physics in part (a)	**0.38**
		Math in part (b)	Physics in part (b)	**0.53**
	Final Exam	Q3 Math	Q3 Physics	**0.26**
		Q4 Math	Q4 Physics	**0.64**
Spring 2005 (n=269) *r>**0.23** indicates strong correlation	Exam 1	Math in part (e)	Physics in part (e)	**0.66**
	Exam 2	Math in part (a)	Physics in part (a)	**0.88**
		Math in part (c)	Physics in part (c)	**0.94**
	Exam 3	Math in part (a)	Physics in part (a)	**0.82**
		Math in part (b)	Physics in part (b)	**0.84**

Strong correlations between math and physics performance → **Possibility of transfer from calculus to physics**

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Interview Results: Fall 2004

- Self-confidence in calculus knowledge retention
- Realization that calculus is required in physics
- Lack of confidence in <u>setting-up</u> physics problems

Students' self-reflections are consistent with our observations.

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Interview Results: Spring 2005

- Consistent with previous interview results
- Criterion on use integration in physics
  - When problems were similar to the examples seen in text (4 out of 7 interviewees)
    - Could not explain why they used integration
    - Could not solve the variation physics problems
  - Use integration to add up infinitesimally small elements (3 out of 7)

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Interview Results: Spring 2005

- Difficulties when applying integrals
  - <u>Determining the variable of integration.</u>
    - *"all constants (variables), I do not know what I should integrate although I know how to integrate…"*
  - <u>Deciding the limits of integration</u>
    - Students usually did not realize they used the wrong limits
  - <u>Origin of difficulties</u>
    - Physics class (majority)
    - Calculus class

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Conclusions

- The strong correlations between students' calculus and physics performance indicates transfer.
- Students believed that for the most part their calculus class has provided them with adequate knowledge and skills required for physics .
- Students believed they did transfer their calculus knowledge when solving calculus-based physics problems.
- Students need external clues to facilitate the transfer process.

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Further Work

- Collect participants' scores in their calculus class and conduct correlation analysis.
- Run hierarchical cluster analysis using all kinds of variables to find how they relate to each other.

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For More Information...

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