Facilitating Students Transfer of Problem Solving in Introductory Mechanics

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Objective and Research Questions

Objective: Facilitate students' transfer of problem solving skills across problems of different contexts and representations

Research Questions:

- What kinds of difficulties do students have when solving problems different contexts and representations?
- How does the sequence in which problems of different contexts and representations are presented to students affect their performance?
- What kinds of scaffolding may help students overcome those difficulties?

Methodology

Teaching/Learning Interviews[1]

- Calculus-based physics volunteers (N = 20)
- Each participant was interviewed 4 times during semester.
- Each interview came after an in-class exam.
- Each interview, the students were:
  - Asked to solve three problems:
    - Original problem: a problem from most recent exam
    - Graphical problem: part of info. given as graph
    - Functional problem: part of info. given as function
  - Asked to think aloud while solving problems.
  - Given verbal hints whenever unable to proceed.

[1]Engelhardt, et. al. 2003

Examples of Interview Problems

Original problem in Interview 2

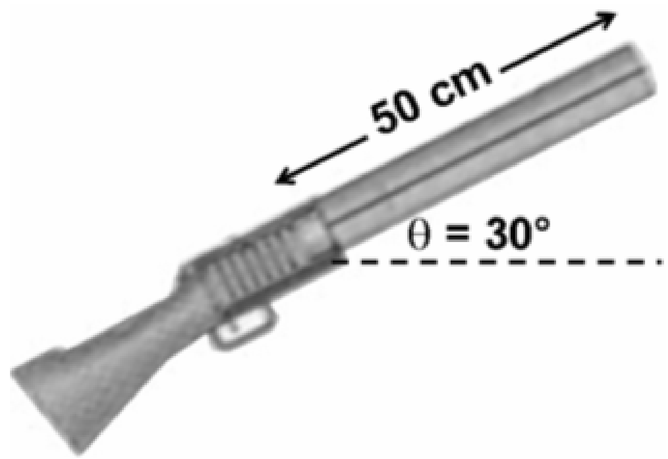
A spring of spring constant 3.0 kN/m is compressed a distance of 1.5 cm and a small ball is placed in front of it. The spring is then released and the small ball, mass 0.1 kg, is fired along the slope and launched into the air at point A which is 10 cm above the spring. The angle θ of velocity at launch is 30°. Friction is negligible.

What is the speed of the ball at the launch point (point A)?

Examples of Interview Problems

Functional problem in Interview 2

A 0.1 kg bullet is loaded into a gun (muzzle length 0.5 m) compressing a spring to a maximum of 0.2 m as shown. The gun is then tilted at an angle of 30° and fired.



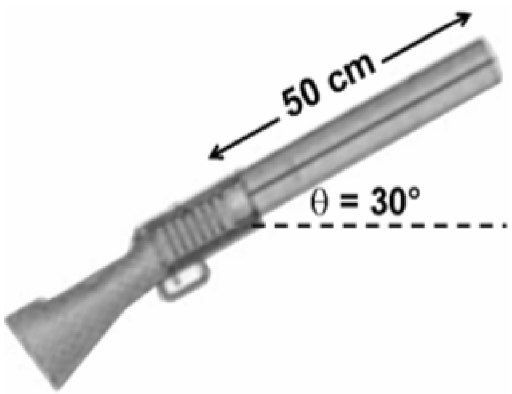
The only information you are given about the gun is that the barrel of the gun is frictionless and that the gun contains a non-linear spring such that when the held horizontal, the net force, F (N) exerted on a bullet by the spring as it leaves the fully compressed position varies as a function of the spring compression, x (m) as given by: $F = 1000x + 3000x^2$

What is the muzzle velocity of the bullet as it leaves the gun, when the gun is fired at the 30° angle as shown above?

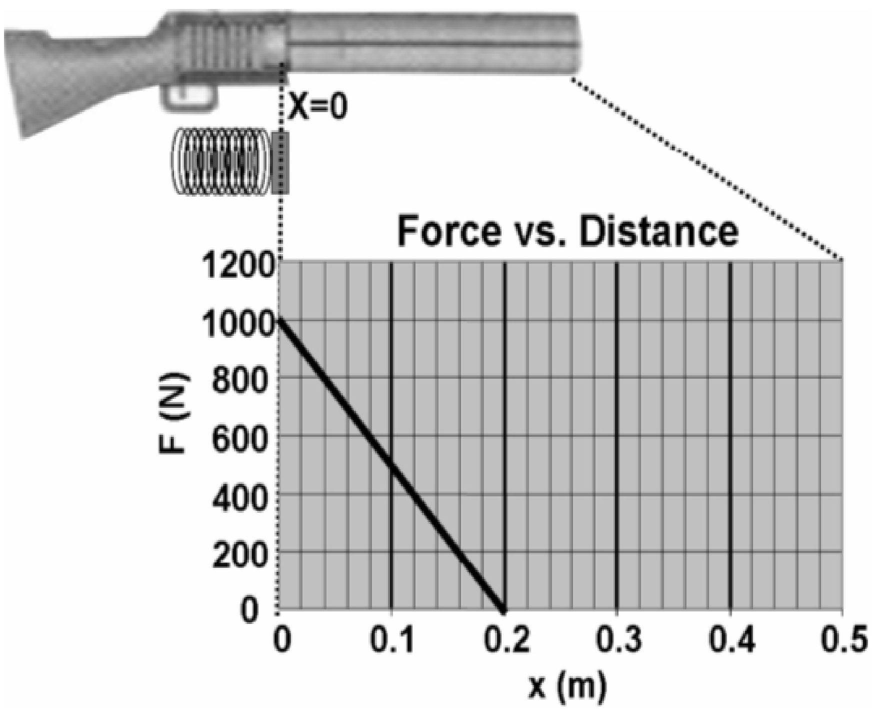
Examples of Interview Problems

Graphical problem in Interview 2

A 0.1 kg bullet is loaded into a gun (muzzle length 0.5 m) compressing a spring as shown. The gun is then tilted at an angle of 30° and fired.



The only information you are given about the gun is that the barrel of the gun is frictionless and when the gun is held horizontal, the net force F (N) exerted on a bullet by the spring as it leaves the fully compressed position varies as a function of its position x (m) in the barrel as shown in the graph below.



What is the muzzle velocity of the bullet as it leaves the gun, when the gun is fired at the 30° angle as shown above?

Results :
Common themes in students' performance

Case Reuse:

- Students tried to mimic the previous problems whenever possible.
- Predictable, but not helpful in most cases in our interviews.
- Example: finding spring potential energy in interview 2.

Interpreting a graph:

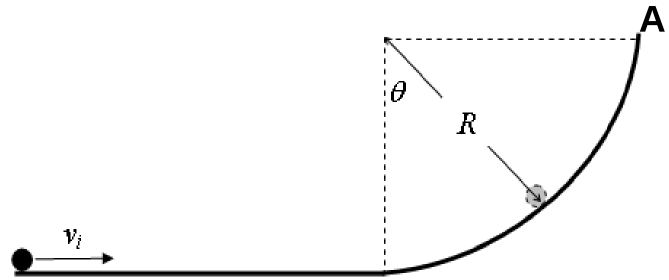
- When given a graph, students always thought of the slope.
- Students needed a lot of hints to recognize integral = area under graph

Results :
Common themes in students' performance

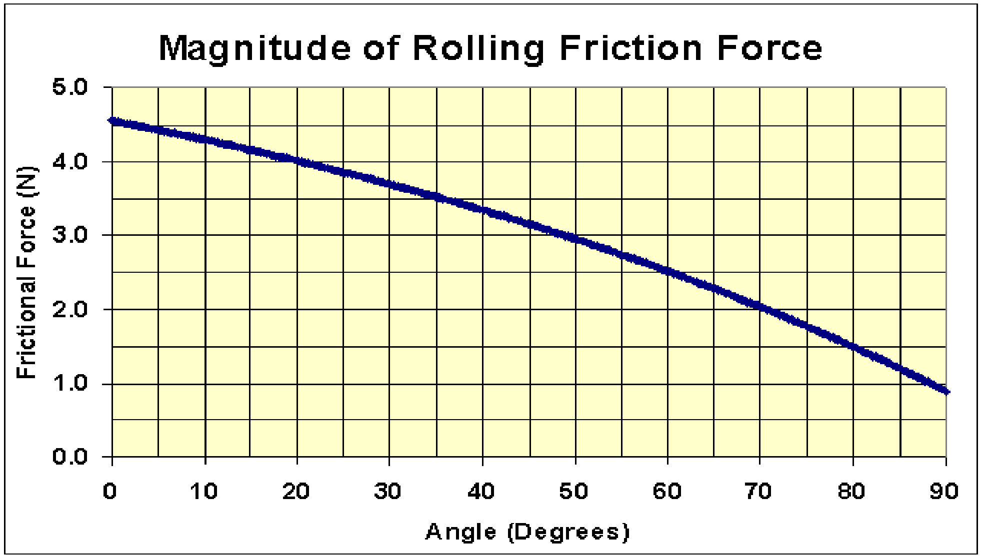
Physical meaning of integral:

- Most students did not know physical meaning of integration.
- Hints on meaning did not make much sense.
- Hints on basic things like units of quantities: more effective.
- Example: graphical problem in interview 4

A sphere radius $r = 1$ cm, and mass $m = 2$ kg is rolling at an initial speed v_i of 5 m/s along a track as shown. It hits a curved section (radius $R = 1.0$ m) and is launched vertically at point A.



The magnitude of the rolling friction force acting on the sphere varies as angle θ as per the graph shown below



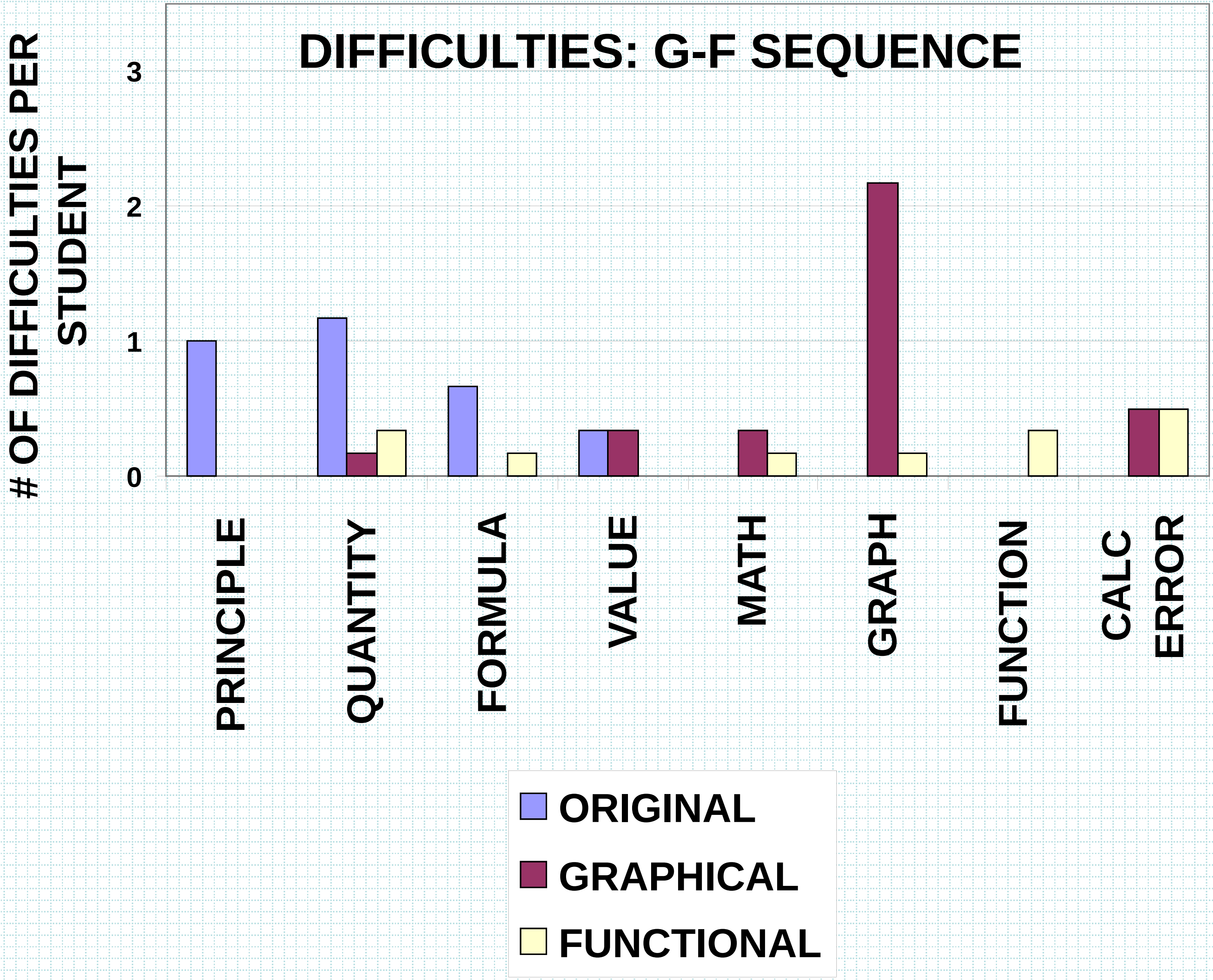
What is the launch speed of the hoop as it leaves the slope at point A?

Results : Difficulties

- GRAPH: unable to process information from the graph provided.
- FUNCTION: inappropriate interpretation or use of the function given.
- PRINCIPLE: inappropriate use of physical principles.
- QUANTITY: incorrect use, calculations, and units of physical quantities.
- FORMULA: incorrectly recalls a formula or interpret meaning of formulae/expressions.
- VALUE: uses incorrect value of physical quantities.
- MATH: unable to manipulate mathematical processes.
- CALCULATION: simple calculation errors.

Results: Hints

- GRAPH: enables students to read off and process information from the graph provided.
- QUANTITY: helps students plan a strategy to find desired quantities using the info. given (e.g. graph, function), or to decide which quantities are applicable in each situation.
- MATH: questions on meaning of mathematical notations and operators.
- PRINCIPLE: enables students to determine the appropriate principle to use.
- INFO: asks students to take a more careful look at the problem statement to gather necessary data.
- FORMULA: helps students understand the meaning of a formula or an equation.
- CALCULATION: helps students recognize and correct simple calculation errors.


DIFFICULTIES: G-F SEQUENCE
OF DIFFICULTIES PER STUDENT
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QUANTITY
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GRAPH
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CALC ERROR
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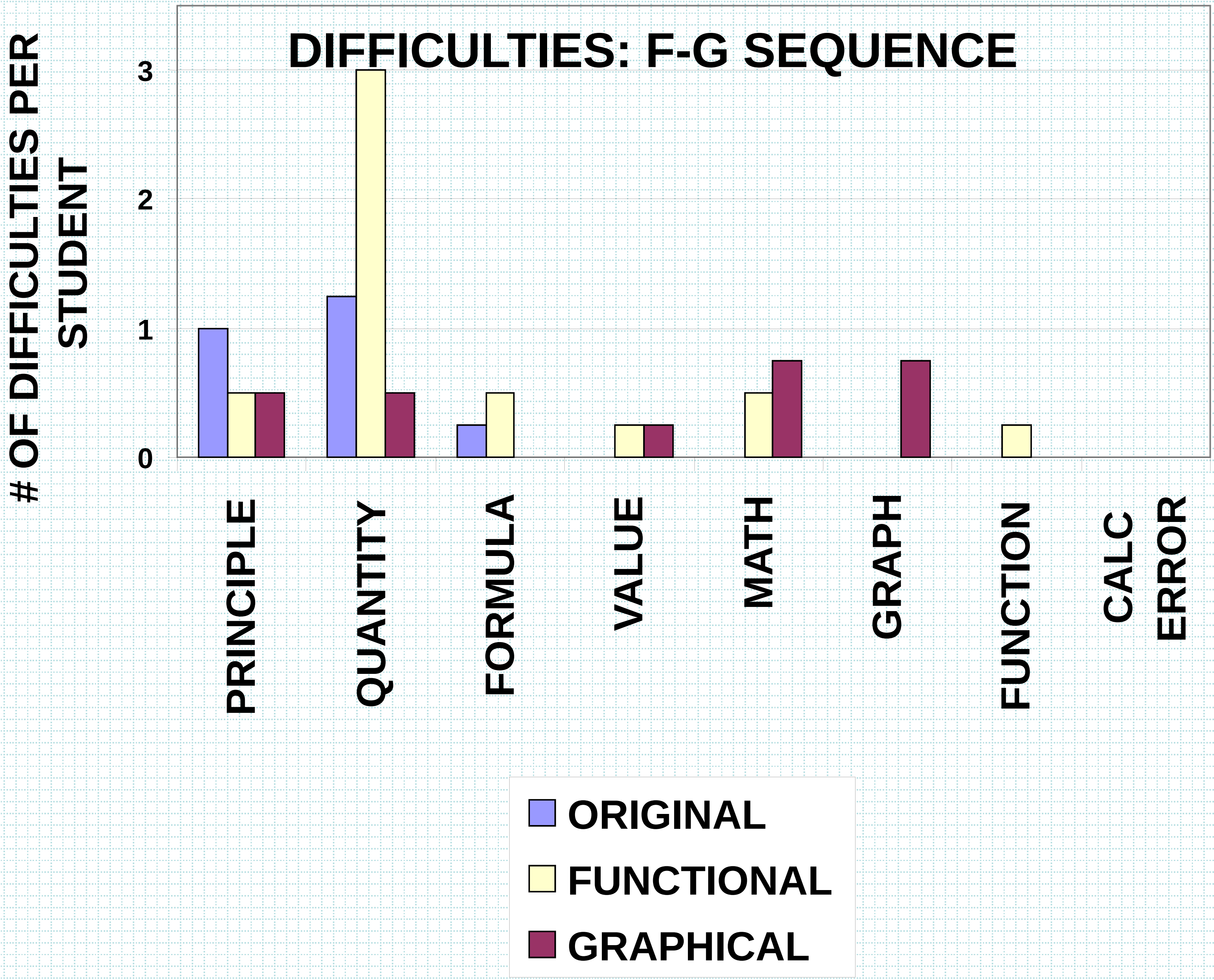
GRAPHICAL
FUNCTIONAL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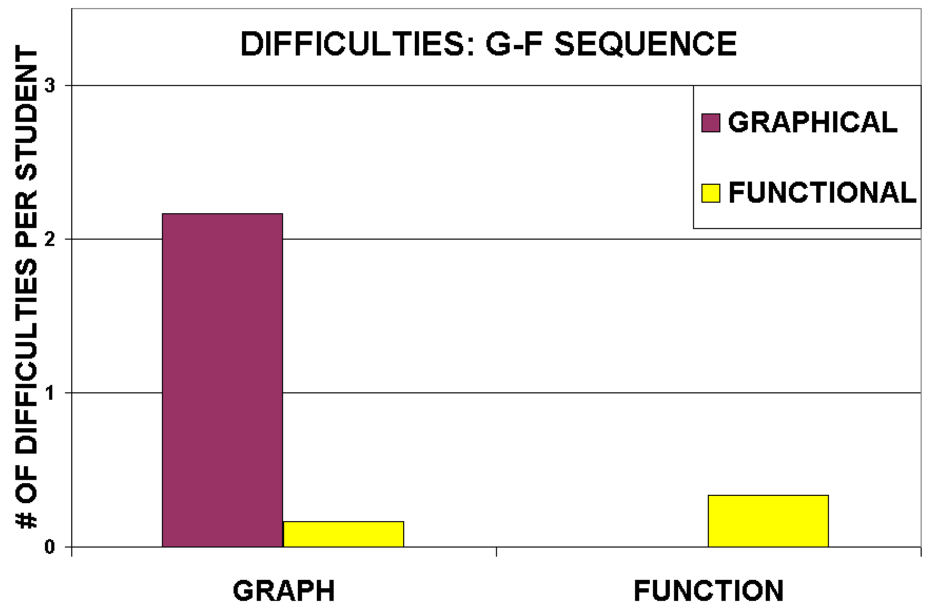
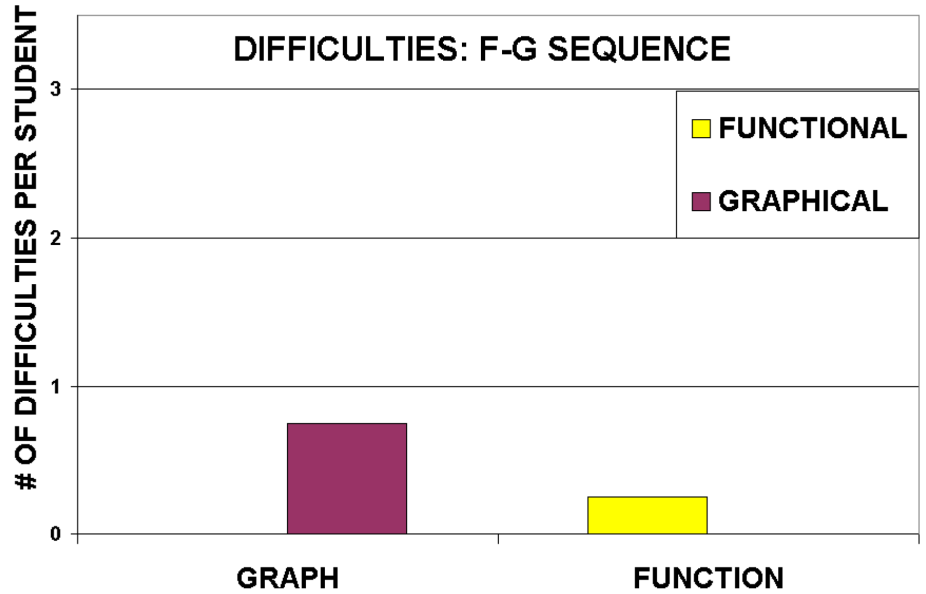
Results : Sequencing Effect

Representational aspect

- G-F sequence: most difficulties with graph
- F-G sequence: minor difficulty with function
- Students' transfer occurs more easily in the F-G sequence than in the G-F sequence.



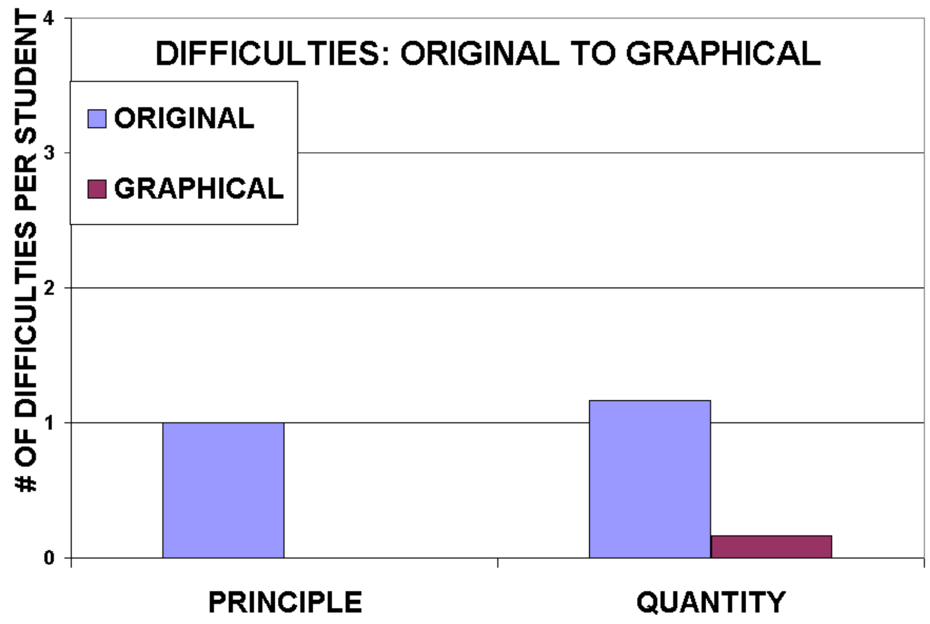


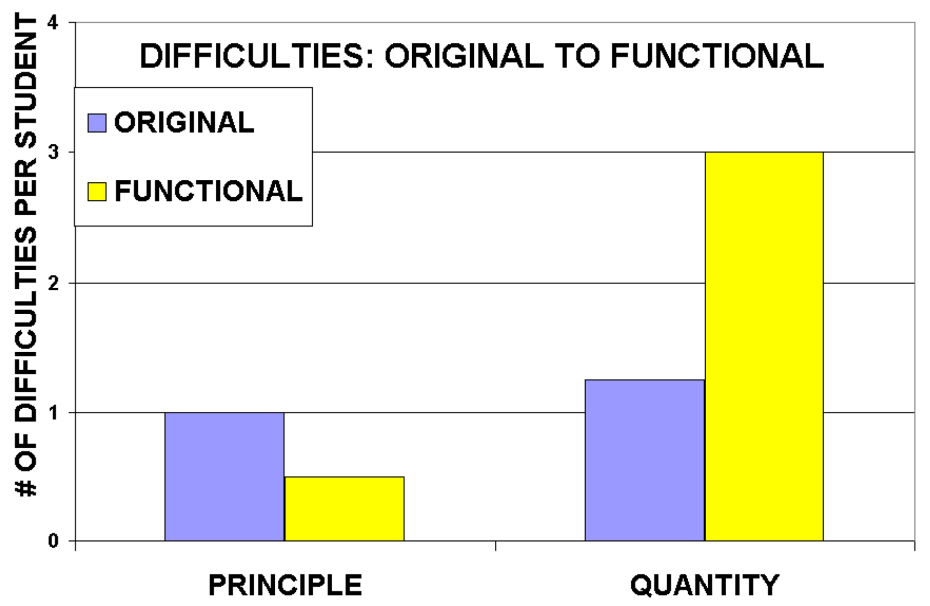
Results : Sequencing Effect

Contextual aspect
(from Original to 2nd problem

- From Original to Graphical: minor difficulties with principle and quantities.

- From Original to Functional: some difficulties with principle and significant difficulties with quantities.





Conclusions

- Students were unable to interpret physical meaning of mathematical operators and processes.
  - Thus had difficulties solving problems in graphical and functional representations.
- When the context of the problem changed, could not relate the new problem to the original problem.
  - Thus had difficulties identifying the principle and physical quantities needed to solve the new problem
- The sequence of problems affected their performance:
  - Representational Change: Easier when Functional problem is presented before Graphical problem.
  - Contextual Change : Harder when accompanied by representational change from Numerical to Graphical

THANK YOU