Students' Perceptions of the Math-Physics Interactions Throughout Spins-First Quantum Mechanics

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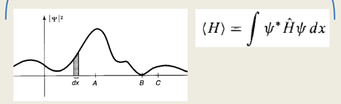
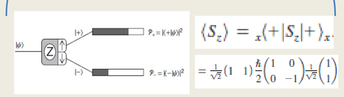
Introduction

- Quantum Mechanics is one of the most challenging physics courses.
  - Involves: complex mathematics and abstract counterintuitive physics
- Lack of robust mathematical preparation hinders students' ability to focus on physics concepts
- Simultaneous efforts to master both math and physics at one can create a cognitive overload.
- One of the purported benefits a spins-first approach to QM is that it allows students to build up QM ideas before introducing the more complicated mathematics used in the context of wave functions.

Positions-First	**Spins-First**
- Schrödinger equation - Wave functions - Integration	- Stern-Gerlach - Spins-1/2 systems - Dirac notation





Methodology

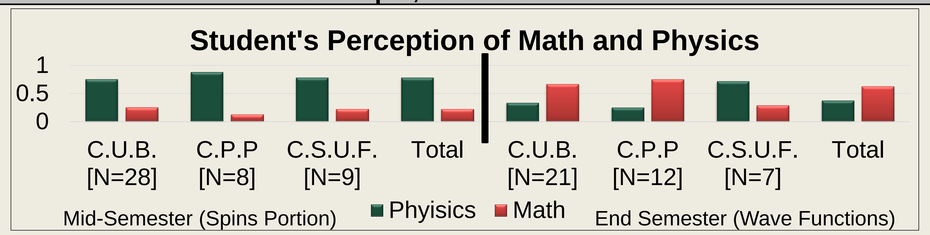
- 3 different institutions teaching spins-first approach:
  - California Polytechnic State University, Pomona (CPP)
  - University of Colorado, Boulder (CUB)
  - California State University, Fullerton (CSUF)

Mid-Semester Survey **End Semester Survey**

Survey Administration → Spins Portion → Wave Functions Portion

Question 1

Compare the role of math and physics concepts. Is the math more challenging than the concepts, or vice versa?



Graph 1: Qualitative student comparisons on the role of math and physics.

- Promising shift in the students perception on the difficulty of math and physics throughout the course
  - Students find the physics more challenging in the Spins portion of the course then switch to find the math more challenging in the Positions portion of the course.
- The shift shows a possible cognitive decrease by having students master the math or physics independently of each other instead of simultaneously.

Why or why not? : Coded Student Responses

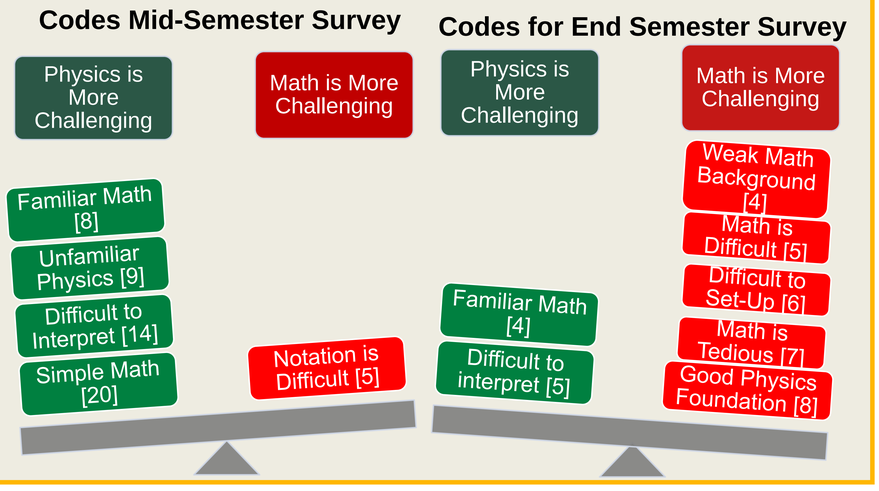
- **Coding Process:** Each response was separated depending on how the student answered the survey question and was designated a code that depended on the student's use of key words/phrases.

I thought the math physics was more challenging because of this reason	Designated Code
In spin systems the concepts was a lot more challenging than the math was This is because the math was very similar to vectors which we've worked with before but the concept of spins was new and more challenging	Familiar Math, Unfamiliar Concepts
The notation and the use of the notation with different new math's was the most difficult	Unfamiliar Math, Notation Is Difficult

Table 1: Two examples of coded student responses.

Code Breakdown:

- Trend is consistent when looking at what the students specifically found difficult.
- The codes shift from being physics focused to math focused.
- Creating a strong physics foundation in Spins-First QM lead to students only finding the math to be challenging instead of both the math and physics during the wave functions portion.



Question 2

On a scale of agree – disagree respond to the following two statements

- The math helps me make sense of the physics
- The physics helps me make sense of the math

Mid-Semester (Spins)		The physics helps me make sense of the math			
School Totals		Agree	Neutral	Disagree	TOTAL
The math helps me make sense of the physics	Agree	39	7	9	55
	Neutral	6	3	2	11
	Disagree	5	4	6	15
	TOTAL	50	14	17	81

Student responses to both questions (Mid-Semester)

End Semester (Wave Functions)		The physics helps me make sense of the math			
School Totals		Agree	Neutral	Disagree	TOTAL
The math helps me make sense of the physics	Agree	32	13	6	51
	Neutral	4	5	3	12
	Disagree	5	1	3	9
	TOTAL	41	19	12	72

Student responses to both questions (End Semester)

- Students throughout the semester acknowledge the interconnectedness of math and physics
  - Despite the shift in whether they found math or physics more challenging than the other.
- One trend seen is that students typically find the math helps make sense of the physics throughout both portions of the course

Please elaborate on your answer to the previous two questions and provide an example.

Codes for Mid-Semester (Spins)		
Understanding Physics ↔ Understanding Mathematics (28)	Understanding Physics → Mathematics (10)	Understanding Mathematics → Physics (27)
Hand in Hand (11)	Physics sets up problems (2)	Math understands how equations behave (4)
	Physics needed for math (1)	Math is familiar (2)
Both Necessary (2)	Physics brings math to life (4)	Math assists in understanding physical concepts (11)
Build On Each Other (12)	Physics concepts help understanding of math concepts (2)	Math is less tedious and distracting (3)
		Math gives confidence to solve physics (1)
Equally Important (3)	Math is Weak (1)	Math gives reasoning for physics (3)
		Prior math helps (3)

Finalized coding schemas for student responses (Mid-Semester)

Codes for End Semester (Wave Functions)		
Understanding Physics ↔ Understanding Mathematics (19)	Understanding Physics → Mathematics (12)	Understanding Mathematics → Physics (16)
Hand in Hand (14)	Physics concepts help understanding of math concepts (8)	Math assists in understanding physical concepts (13)
Both Necessary (2)	Physics concepts made math concept easier (2)	Math is what drives learning (2)
Build On Each Other (3)	Physics brings Math to Life (2)	Math understands how equations behave (1)

Finalized coding schemas for student responses (End Semester)

- Finalized coding schemas nearly identical for both Mid-Semester and End Semester.
- Students comments highlight perceived connections between mathematics and physics
- During the Mid-Semester, students' responses lean heavily towards mathematics helping them understand the physics.
  - This supports the idea that the easier mathematics supports learning counterintuitive physics
- End of semester responses are more evenly distributed; at a point where the physics has been established but the mathematical context is seen as more challenging
- For both Mid-Semester and End Semester student responses largely fell under the category "Understanding Physics ↔ Understanding Mathematics"

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