Piloting i-Newton for the Experiential Learning of Dynamics

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The Problem

- Newtonian dynamics is the foundation for STEM education [1]
- Students often have fundamental misconceptions of Newton's laws [2]

The Proposed Solution

- Introduce hands-on learning via Interactive-Newton (i-Newton) in traditional lecture-based class

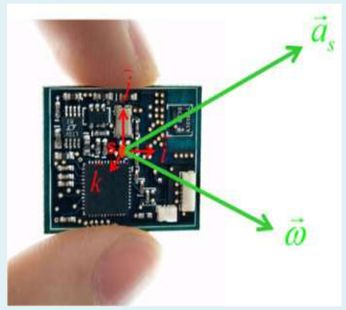
Objectives for this Project

- Develop i-Newton instructor demonstrations for ME 240
- Investigate impact on student understanding of Newtonian concepts
- Determine impact on student self-efficacy, intention to persist in the major, and sense of inclusion

ME 240:Introduction to Dynamics and Vibrations

- Required course for ME, Aero, and NAME; Elective for IOE
- Covers three-dimensional motion of particles; planar motion of rigid bodies; and elementary vibrations
- Taught in traditional lecture-based format
- Serves 400-450 juniors and seniors annually

Demographic Data	All students (N=371)	Control (N=187)	Intervention (N=184)
Gender			
Male	291 (78%)	149 (80%)	142 (77%)
Female	80 (22%)	38 (20%)	42 (23%)
Ethnicity			
White, Not of Hispanic Origin	256 (69%)	136 (73%)	120 (65%)
Asian	80 (22%)	33 (18%)	47 (26%)
Hispanic/Latino	13 (4%)	4 (2%)	9 (5%)
Two or more	11(3%)	5 (3%)	6 (3%)
Unknown/Do not wish to report	10 (3%)	8 (4%)	2 (1%)
Black/African-American	1 (<1%)	1 (<1%)	0 (0%)



i-Newton

- Innovative/inexpensive technology for demonstrating Newtonian mechanics
- Miniature inertial measurement unit (IMU) to wirelessly transfer motion data
- Can be attached to any object
- Generates motion data that can be collected/reviewed in real time

Dynamics of Pendulum Motion

- Canoe paddle with i-Newton on blade
- Angular velocity used to study free oscillations of pendulum and for subsequent analysis

Inertial Properties of Humans

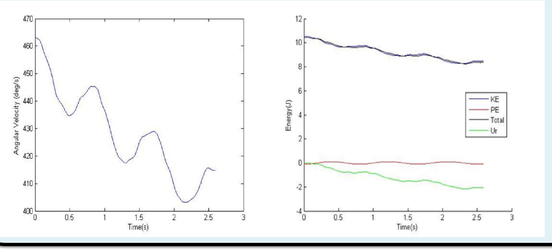
- i-Newton on spinning wheel with and without human rider
- Angular velocity data used to estimate of the moment of inertia of the wheel and also the seated subject.

Energetics of Pogo-Stick Jumping

- Pogo-stick jumper with i-Newton on belt
- Vertical acceleration used to analyze kinematics and energetics of jumping

Dynamics of an Eccentric Wheel

- Bicycle wheel with i-Newton on spokes
- Angular velocity of the wheel during spin-up and rolling motions used to study rigid body dynamics



Example Data Output

Experimental results for rolling bicycle wheel. (a) Wheel angular velocity for three cycles of rolling. (b) Computed wheel energetics including kinetic energy (KE), potential energy (PE), total mechanical energy (Total), and work done by dissipation (Ur).

Results

Significantly higher gains ($p<0.001$) for intervention group

- Concept 6: Kinematics of rolling without slip (RW/OS)
- Concept 8: Zero velocity does not imply zero acceleration and conversely (ZV≠ZA)
- Course specific self-efficacy

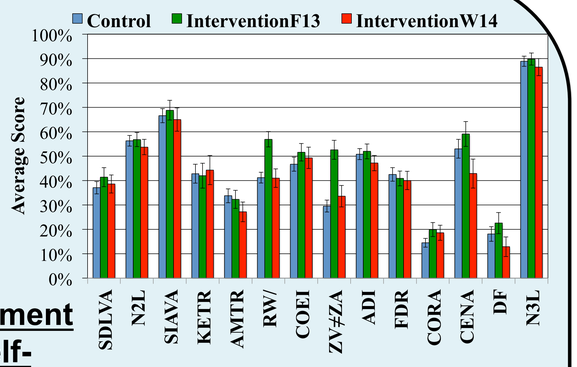
Preliminary Conclusions

i-Newton is successful:

- It enables hands-on learning without traditional laboratory
- It has potential to increase understanding of Newton's laws
- It can be adapted to other courses that emphasize Newton's laws (e.g., Introductory Physics)
- Student-directed experiments could result in even greater benefits

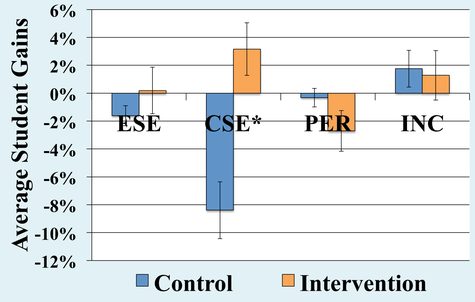
Dynamic Concept Inventory (DCI)[3]

- 29-multiple choice items
- Assesses 14 misunderstood topics in rigid body dynamics



Longitudinal Assessment of Engineering Self-Efficacy (LAESE)[4]

- 29 Likert scale items (0 = strongly disagree to 5 = strongly agree)
- Assesses four separate constructs:
- Self-efficacy (SE)
- Course specific self-efficacy (CSE)
- Intentions to persist in the field (PER)
- Feelings of inclusion (INC)



Future Work

- Increase the number of hands-on experiments
- Map experiments to all the 14 DCI concepts
- Add more sections that implement i-Newton

Acknowledgements

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References

1. E. L. Lewis, "Conceptual change among middle school students studying elementary thermodynamics," 1996.
2. J. Confrey, "A Review Of The Research On Student Conceptions In Mathematics, Science, And Programming," 1990.
3. G. L. Gray et. al. "Toward a Nationwide Dynamics Concept Inventory Assessment Test, 2003.
4. R. M. Marra and B. Bogue, "Women Engineering Students' Self Efficacy – A Longitudinal Multi - Institution Study," 2006.