



Parachute Courses: Reducing DFW Rates in Introductory Calculus-based Physics

Jeff Saul and Patrick Coulombe
jsaul@stemedolutions.com
Tiliadal STEM Education Solutions





General Physics 1 is a Killer Course

with or without calculus DFW rates of 20-60%

Why?

- Course covers an **enormous amount of material** – often better than a chapter a week
- **Assumes a good understanding** of math prerequisites
-- Algebra, Trigonometry and often Calculus
- **Many concepts are counter-intuitive**
- Students **learning new thinking and math skills** as well as new content
- **Often hard to visualize** what is going on
- Course structure based on **premise that students had physics in high school**



Defining the problem

- * If we want more students to earn STEM degrees, we need introductory physics to be more of a pump, than a filter.
- * How do we keep more students in the STEM pipeline with an introductory physics sequence that assumes students have a good background from prior math and physics classes?
- * How do we improve student learning outcomes and passing rates?





Defining the problem further:

Two key needs

- * Without changing the course, how do we bring students who fail General Physics 1 to where they need to be, so they can be successful when they retake it.
- * How do we keep students from failing the first time so they don't risk losing scholarships/financial aid (reduced credits, lower GPA).



Background

- Southwestern urban university
less <10% of students living on campus
- Academic rating = 180th tied
(US News & World Report 2016 Best Colleges)
Engineering College ranked 14th nationally (Princeton Review)
- Enrollment = 27,000 students (20,000 undergraduates)
- Student average age = 24
large fraction of 1st generation college students



Background

- Student Population:
40% Hispanic / 5% Native American
- Many students on scholarship;
most provided by state lottery scholarship program
- Six year graduation rate is 47%
- Freshman retention rate is 77%



General Physics 1

- Course is primarily for engineering majors / some physics majors
- 3 credit 3 hours/week lecture in 275-student lecture hall with excellent demonstration facility attached
- Optional 1 hour/week problem solving (discussion) section taught by lead instructor – taken by 10-40% of students
- Optional (required by some majors) separate 1 credit 3 hour/week lab
- **DFW (failure to pass with a C or better) rate of 40-70%**



Solution = A Parachute Course

Make it a parachute course:

- A course that students can **switch into mid-semester** (2nd half-semester course), **giving them a 2nd chance** in General Physics 1 and **preventing them from failing**
- **Help students build the skills and knowledge** they need to be successful in General Physics 1





Solution = A Parachute Course

- **More intense**, Four 75 minute meetings per week
- Uses integrated lecture/lab with **activity-based learning**
- Have it meet before 9 AM => **minimal interference with other classes** (or after 6 PM)





Course Format

- Physics 110 meets MTuWTh from 7:30-8:45 AM in a lab or studio classroom
- **Students sign form to switch** into the Parachute Course;
Register processes form manually to remove General Physics 1 from student transcript and add Parachute Course
- **No cost to students for switching**; Instructor switches students online homework & e-textbook that emphasizes conceptual understanding, visualizations, & problem solving
- Until recently, some students take Parachute Course as **physics prep class** to prepare for General Physics 1 (more later)



Course Format

- Curriculum is adopted from award-winning high school curriculum => ASU Modeling Instruction with extra material on problem solving, vector analysis, & symbolic algebra
- Mostly learning by doing, minimal lecturing
- Each activity ends with student group(s) presenting work to class - followed by class Q and A discussion
- Course pace slower with less homework than General Physics 1
- Students can pass with a C with good effort, but students told B or better is needed to succeed when retaking General Physics 1



Typical Unit

- **Starts with visualization** diagrams and/or graphs from observations and experiments
- **Key Ideas & Equations are derived** from experiments & observations
- Students **summarize each activity** on a whiteboard
- End of each activity is a white board Q & A session
=> **board meeting - groups get up and present** activity results



Typical Unit (cont.)

- Problem worksheets assigned to **practice applying concepts**
- Students **work in groups** on worksheets in class and **present/discuss results in class** before submitting as homework
- **Sometimes follow-up experiments** are used to modify/deepen the model
- General Physics 1 **HW problems assigned in Mastering Physics**



Emphasis on Good PS Practice in class

- Students **are taught an expert problem solving strategy**
SPS – Strategic Problem Solving
- Start by **visualizing the problem** with diagrams and graphs
- Then **identify the key concept(s)**
- **Working problems step-by-step on paper**
- Every calculation is preceded by **solving for the unknown in symbols** => all algebra done in symbols
- Course material is centered on **building, understanding, and applying essential force & motion models**

Sample Whiteboards

PREPARE:

x_0
 v_{0x}
 t_0

x_1
 v_{1x}
 t_1

Δx Δt

a

KNOWNs:
 $v_0 = 15 \text{ m/s}$
 $\Delta x = 25 \text{ m}$
 $v_1 = 0 \text{ m/s}$

UNKNOWNs:
 Δt ✓
 a ✓

Physics
 Particle model
 Assume/observe
 • Road is flat & straight.
 • The car is slowing down a constant acceleration model

SOLVE:

$$v_1^2 = v_0^2 + 2a\Delta x$$

$$\frac{v_1^2 - v_0^2}{2\Delta x} = a$$

$$\frac{(0 \text{ m/s})^2 - (15 \text{ m/s})^2}{2(25 \text{ m})} = a$$

$$* \frac{-225 \text{ m}^2/\text{s}^2}{50 \text{ m}} = a$$

$$\boxed{-4.5 \text{ m/s}^2 = a}$$

$$v_1 = v_0 + a\Delta t$$

$$\frac{v_1 - v_0}{a} = \Delta t$$

$$\frac{(0 \text{ m/s}) - (15 \text{ m/s})}{-4.5 \text{ m/s}^2} = \Delta t$$

$$* \frac{-15 \text{ m/s}}{-4.5 \text{ m/s}^2} = \Delta t$$

$$* \boxed{3.3\bar{3} = 3.3 \text{ s} = \Delta t}$$

ASSESS:

SEE UNIT CANCELLATION AT *S

8.

$F_{N,F\rightarrow B}$
 $F_{f,F\rightarrow B}$
 $F_{g,E\rightarrow B}$
 $F_{p,M\rightarrow B}$

F_N
 F_g
 $F_{f,F\rightarrow B}$
 $F_{N,F\rightarrow B}$

5.0 N
 50°
 2 kg
 F_N
 F_g

$F_{\text{net}} = 0$

man (m)
 Broom (B)
 Floor (F)
 Earth

a) $a_y = 0$ iff $\sum F_y \rightarrow B = 0$
 $0 = F_{N,F\rightarrow B} + F_{g,E\rightarrow B} + F_{p,M\rightarrow B} + F_{f,F\rightarrow B}$
 $F_{N,F\rightarrow B} = (2.0 \text{ kg})(9.8 \frac{\text{m}}{\text{s}^2}) - \sin(50^\circ) 5 \text{ N}$
 $F_N = 15.8 \text{ N}$
 $F_N = 16 \text{ N}$

b) $a_x = 0$ iff $\sum F_x \rightarrow B = 0$
 $0 = F_{N,F\rightarrow B} + F_{g,E\rightarrow B} + F_{p,M\rightarrow B} + F_{f,F\rightarrow B}$
 $0 = (5 \text{ N}) \cos(50^\circ) + F_{f,F\rightarrow B}$
 $F_{f,F\rightarrow B} = 3.21 = 3.2 \text{ N}$

8)

5 N
 (50°)

$m = 2.0 \text{ kg}$
 $\vec{a} = 0$
 $a_x = 0$ iff $\sum F_{x \text{ broom}} = 0$
 $0 = F_g^x + F_{N,E\rightarrow B}^x + F_{N,W\rightarrow B}^x$
 $0 = -mg + F_{N,E\rightarrow B}^y + F_N(\sin(\theta))$
 $-5 \text{ N}(\sin 50^\circ) + mg = F_{N,E\rightarrow B}^y$
 $-(3.8 \text{ N}) + (2.0 \text{ kg} \cdot 10 \frac{\text{m}}{\text{s}^2}) = F_N^y$
 $-3.8 \text{ N} + 20 \text{ N} = F_N^y$
 $F_{N,E\rightarrow B}^y = 16 \text{ N}$

F_N
 $F_{N,E\rightarrow B}$
 $F_{N,W\rightarrow B}$
 $F_{g,E\rightarrow B}$

Man
 Broom (B)
 Floor (F)
 Earth

5 N
 $\theta = 50^\circ$
 $F_N \sin 50^\circ = F_y / 5 \text{ N}$



Does it work?

Two criteria

1. Helping struggling students in General Physics 1 not fail and maintain their semester credits and their GPA
2. Helping students develop knowledge and skills needed to pass General Physics 1 course when they retake it



Criteria 1

1. Helping struggling students in General Physics 1 not fail and maintain their semester credits and their GPA
 - 79% of students taking the parachute class passed with at least a C.

TABLE 1. UNM Physics parachute course results over 11 semesters.

Term	Course Size	DFWs	B or Better
Fall 2009	21	3	12
Spring 2010	25	2	13
Fall 2010	25	7	12
Spring 2011	31	9	11
Fall 2011	40	3	19
Fall 2012 [12]	54	8	12
Spring 2013	26	8	8
Fall 2013	43	6	32
Spring 2014	16	4	7
Fall 2014	29	10	13
Spring 2015*	75	22	34
Totals	385	21%	45%

* Large student numbers required teaching parachute course as an evening section in physics lecture hall.



Criteria 2

2. Helping students develop knowledge and skills needed to pass General Physics 1 course when they retake it
 - This was trickier. Coulombe did a longitudinal study of students who retook General Physics 1
 - 105 students took the parachute course before retaking
 - 180 students retook the course without taking parachute course



Criteria 2

2. Helping students develop knowledge and skills needed to pass General Physics 1 course when they retake it
 - Coulombe did a longitudinal study of students who retook General Physics 1
 - Letter grades converted to 12 point numeric scale
 - Ran linear regression analysis using R (Lavaan equation modeling package) of several factors including student GPA and SAT/ACT.



Criteria 2 Results

2. Helping students develop knowledge and needed to pass General Physics 1 (GP1) course when they retake it
 - Although students who did not take the parachute course has a slightly lower mean grade when retaking GP1 (C vs. C+, $p < 0.447$, not statistically significant)
 - Students who passed parachute class with a grade lower than B had lower mean grade when retaking GP1 than students who passed with a B or better (C- vs. C+/B-, $p < 0.001$, is statistically significant)



Criteria 2 Results

2. Helping students develop knowledge and skills needed to pass General Physics 1 (GP1) course when they retake it
 - Students who passed parachute course with B or better had a higher mean grade when retaking GP1 than students who retook GP1 without taking the parachute course (C+/B- vs. C/C+, $p < 0.01$, is statistically significant)
 - However, when students' GPA taken into account, this last result is no longer statistically significant ($p < 0.716$)
 - Student GPA correlated strongly with grade in GP1 in general (Wald $z = 12.58$ $p < 0.001$)



Criteria 2 Results

- Students who passed parachute course with B or better had a higher mean grade when retaking GP1 than students who retook GP1 without taking the parachute course (C+/B- vs. C/C+, $p < 0.01$, is statistically significant)
- However, when students' GPA taken into account, this last result is no longer statistically significant ($p < 0.716$)

This result suggests that of the students switching or dropping GP1, the students with higher GPA (better students?) are taking the parachute course.



Result Summary

- The current Parachute Course does a good job of improving student retention by **helping students maintain their GPA** (79% success rate).
- For students in the Parachute Course, **achieving a “B” or better helps students succeed when retaking General Physics 1**
- Although at first glance, it looks like the Parachute Course helped students achieving a “B” or better in that course performed better in General Physics 1, the difference closes to statistical insignificance when students’ general GPA is taken into account.



Discussion

- Further study is needed to determine whether the Parachute Course helps students succeed when retaking General Physics 1
 - If not, then a redesign to make the course more effective or other options should be considered
- A similar course at University of Illinois has changed to a full semester prep class that students can switch into from General Physics 1 during the add/drop period (Gary Gladding).
- At this school, a one-semester prep class has been implemented in parallel with the parachute course. The students who previously took the parachute course as a prep course not take this class.



Thought for the day: A good engineer is one who has made the right mistakes and learned from them

For more information: Contact Jeff Saul
jsaul@stemedolutions.com

