Addressing Student Success Through Strategic Curriculum Pathways

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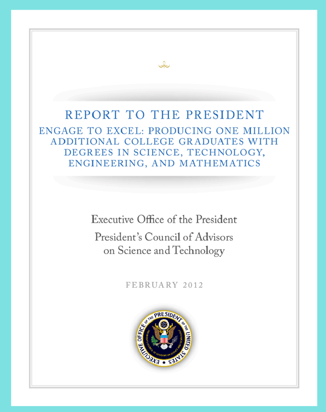
National Need



"Economic projections point to a need for approximately 1 million more STEM professionals than the U.S. will produce at the current rate over the next decade…"

Currently, about 300,000 STEM degrees are awarded annually. Of those that start the path to a STEM degree, only about 40% actually complete it. A 10% increase in retention alone would generate 0.75 million degrees over the next decade.[1]

The Need at Clarkson

Approximately 70% or more of students that come in to Clarkson are in majors that require 6 or more introductory Science, Technology, Engineering and Mathematics (STEM) courses.

Year	STEM	%
'06-'10	2298	69.6
2011	598	75.7
2012	562	77.2
2013	583	77.7
2014	585	81.9
2015	597	81.1

In our Historical data set (defined as the years 2006 to 2010), the retention rate for Clarkson University was around 86.5%, and in the STEM majors (as described above) was around 90%.

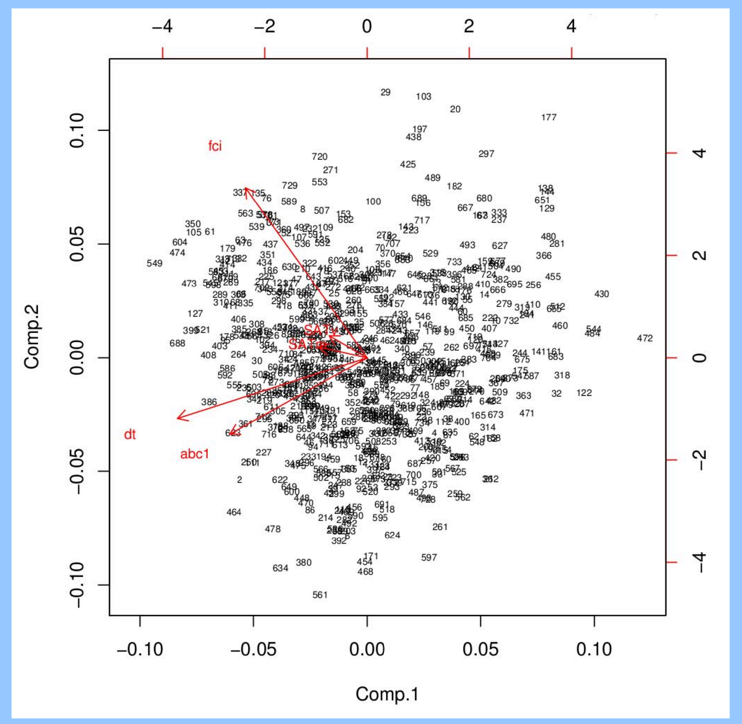
Can we use data collected before the students arrive to help improve these retention rates and better place students for greater success in their STEM disciplines?

Identifying Students and Risk Categories

Data is collected before a student arrives at Clarkson, or within the first week of classes:

- Force Concepts Inventory (FCI)[2] – Survey collected as a Pre/Post test to measure learning "gains"
- CU Mathematics Diagnostic Test (DT)[3] – Survey collected in May of students' senior year of high school
- SAT Mathematics and ACT Equivalent (SATm) – Scholastic Aptitude Test (mathematics)
- SAT Verbal and ACT Equivalent (SATv) – Scholastic Aptitude Test (verbal)
- Absolute Basic Competency (ABC1) – Test in Mathematics, given with Calculus 1 (MA131)

Principle Component Analysis (PCA) is used to see which parameters give the greatest variance in the data set, to attempt to make a low-dimensional model. The orthogonality of the red vectors tells us which ones are least correlated, and best suited to be used in a two-dimensional model.



According to PCA, the FCI and the Diagnostic Test are the best candidates to use in a model to predict student success in the first year.[4] The ABC1 is given after the students are in classes, and is not well suited for our purposes.

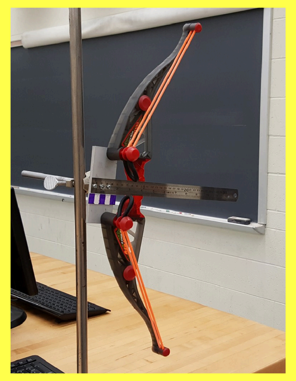
Medium Risk: M-,P+

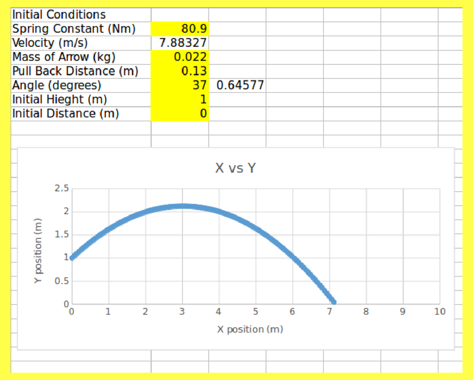
CoOperative Math and Physics Assessment for Student Success (COMPASS)
NSF DUE IUSE #1431882

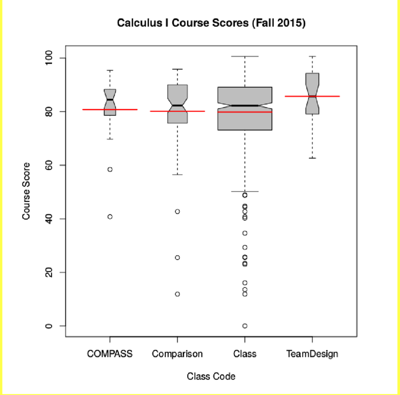
Students in the M-,P+ group are identified as having a medium risk for being unsuccessful in their Early STEM career. These students are identified as having a relative weakness in their mathematical skills, but a greater understanding of basic physics concepts. We leverage these strengths to increase their mathematical ability by reordering the topics taught in introductory calculus to more directly support the topics in physics.[5]

Physics I Topics	Calculus I Topics
Kinematics	Rate of change, derivative, anti-derivative
Forces	Systems of equations, maxima and minima
Work, energy, momentum, impulse	Anti-derivative, integrals, continuity, limits
Rotational motion, oscillations	Trigonometric functions

In the physics laboratory, the curriculum was changed to an early research experience. The students form teams, and complete a series of laboratories that explore different aspects of a single problem throughout the semester. The data that is collected in each experiment is used in a prediction tool, which is validated in a series of challenges.







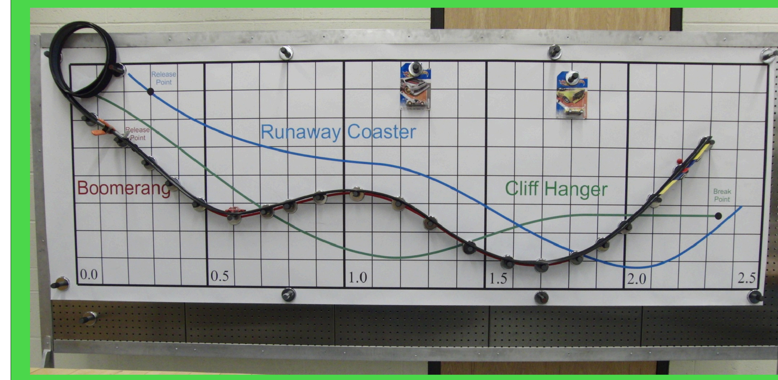
Measurable Outcomes

Despite COMPASS students' relative weaknesses in terms of their pre-enrollment math diagnostics scores, their Calculus I course performance is comparable to the entire class, who have higher pre-enrollment math diagnostic scores.

Low Risk: M+,P+

Physics Team Design Project

Students in the M+,P+ group are identified as having a low risk for being unsuccessful in their Early STEM career. These students are identified as being well prepared for both physics and calculus. The students in this category make up the majority of the students who volunteer to take part in an advanced math/physics lab experience, though any student enrolled in Physics I may take part in the lab.



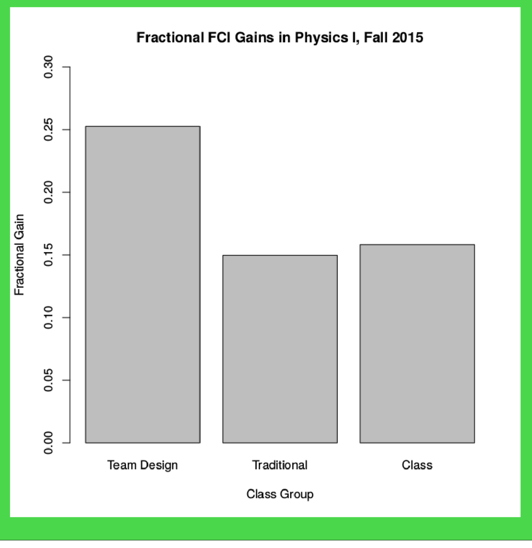
The early research experience takes the form of the mathematical modeling of the motion of a toy car on an arbitrary track. Students build up a mathematical model, beginning very simply, and adding in physical effects as the semester progresses.[6]
The experience culminates with a challenge session, where the students compete to test their models on increasingly difficult tracks.

Measurable Outcomes

A measure used to quantify the gain in knowledge in Physics I & II at Clarkson University is the *fractional gain* of a student or group of students on the FCI. This is given by

$$\frac{\langle post - pre \rangle}{\langle 1 - pre \rangle}$$

where post and pre refer to the post-test and pre-test scores respectively. The Team Design students consistently have a higher gain than students in the traditional labs.



High Risk: M-,P- & M-,P-+

Delayed Physics Program

Students in the M-,P- and M-,P-+ groups are identified as having a high risk for being unsuccessful in their Early STEM career. These students have relative weaknesses in both physics concepts and mathematical skills. The students in this category undergo a schedule change in their common first-year curriculum. The physics sequence of courses is delayed by a semester, and replaced in the first semester by an alternative STEM course that is required for their degree.

First Semester		Second Semester	
Course Title	Credit Hours	Course Title	Credit Hours
Chemistry 1	4	Chemistry 2	4
Physics 1	4	Physics 2	4
Calculus 1	3	Calculus 2	3

Curriculum Modification

First Semester		Second Semester	
Course Title	Credit Hours	Course Title	Credit Hours
Chemistry 1	4	Chemistry 2	4
Alt. STEM	3	Physics 1	4
Calculus 1	3	Calculus 2	3

The rationale behind delaying physics is to enable these students to use the first semester to strengthen their mathematical skills before applying them in Physics.

Measurable Outcomes

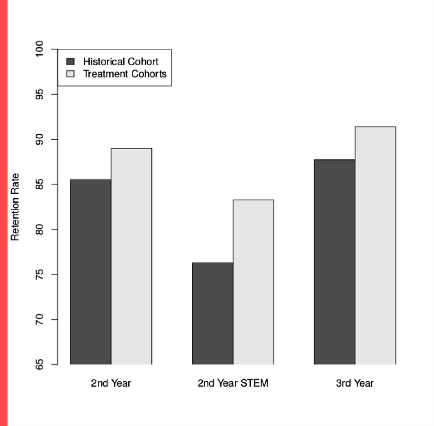
The unsuccessful rates among the high risk students has gone down since the introduction of the program, with an improvement of approximately 50% over the historical baseline.

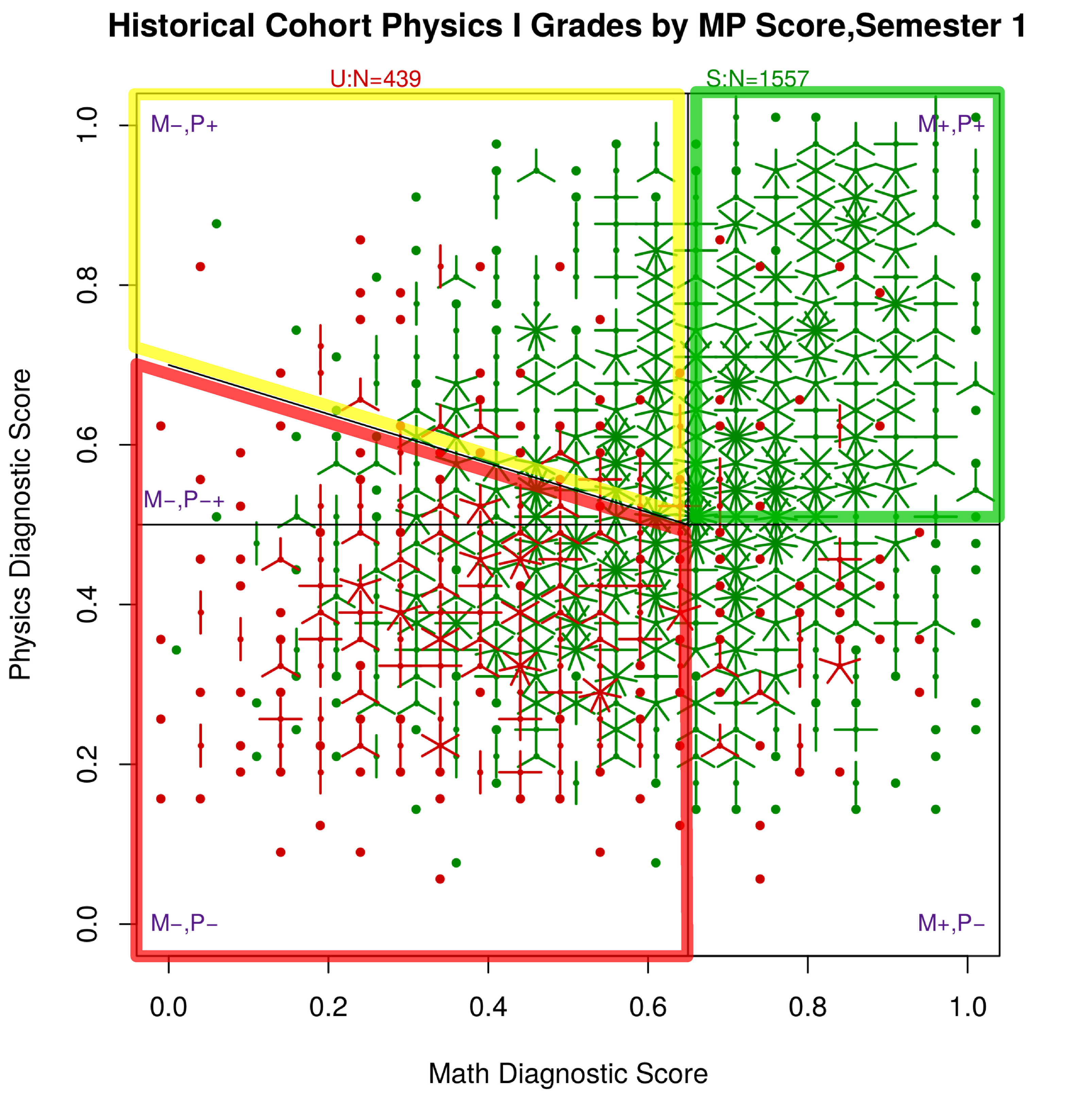
Cohort	%U
Hist.	38.9
2011	26.3
2012	28.3
2013	10.2
2014	18.9
2015	13.3

Cohort	Chem. I	Calc. I	Phys. I
Hist.	1.90	1.85	1.79
2011	2.18	1.84	2.26
2012	2.14	2.36	2.22
2013	2.41	2.61	2.86
2014	2.16	2.13	2.80
2015	2.25	2.40	2.83

The mean GPAs of the students who have gone through the Delayed Physics Program have improved from the historical baseline. Almost all of the improvements have been shown to be statistically significant as well.

The retention rates of the students who have gone through the Delayed Physics Program have improved from the historical baseline. The most impressive improvement is in 2nd year retention in STEM. All of the improvements are statistically significant.





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References

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- [2] D. Hestenes, M. Wells, and G. Swackhamer, "Force Concept Inventory," The Physics Teacher, vol. 30, no. 3, pp. 141–158, 1992.
- [3] P. R. Turner, "A predictor-corrector process with refinement for first-year calculus transition support," PRIMUS, vol. 18, no. 4, pp. 370–393, 2008.
- [4] P. D. Schalk, D. P. Wick, P. R. Turner, and M. W. Ramsdell, "IMPACT: Integrated Mathematics and Physics Assessment for College Transition," in *Frontiers in Education Conference, 2009. FIE'09. 39th IEEE, pp. 1–6, IEEE*, 2009.
- [5] "NSF Award Search: Award#1431882 - COMPASS: CoOrdinated Math-Physics Assessment for Student Success." http://www.nsf.gov/awardsearch/showAward?AWD_ID=1431882
- [6] Modeling the Motion of a Toy Car Traveling on an Arbitrarily Shaped Track, Wick, D. P., Ramsdell, M. W., American Journal of Physics, 70, 670 (2002)