Learning Theory and Analytics as Guides to Improving Undergrad STEM Education

Matthew L. Bernacki, PhD

Department of Educational Psychology & Higher Education

MALT•lab Research on Metacognition and Motivation in Advanced Learning Technologies

THE NEED

[UNLV] students tend to struggle adjusting to college, and it influences their learning and achievement.

THE OPPORTUNITY

Research on Learning can supply students with strategies to learn.
Data on individual students can help us tailor the way we support them.

The research question

How do we help students learn to learn?
…and how do we tailor our support to the individual?

LearningTAGs Overview

Provide students with resources to support learning.

Teach them to use them.

Identify students likely to struggle, and reach out.

Let the others be.

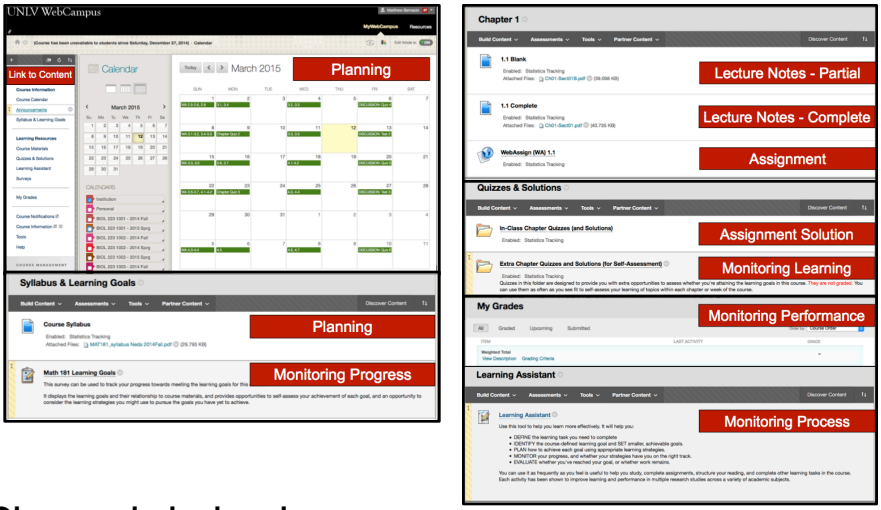
Learning Theory and Analytics as Guides to Improving Undergrad STEM Education

Research Questions

- How do students use resources?
- Which behaviors are related to achievement?
- How motivated are students to learn?

STUDY 1
PROVIDE STUDENTS WITH RESOURCES.

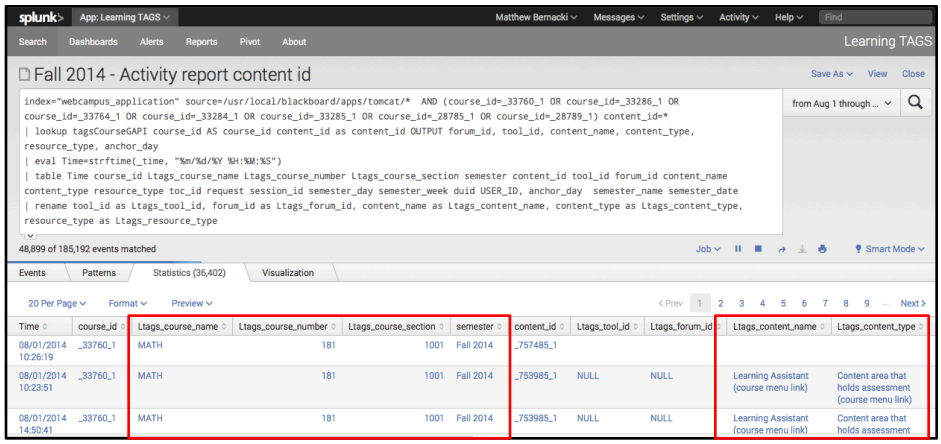
Study 1: Resources for Learning



Observe student use!

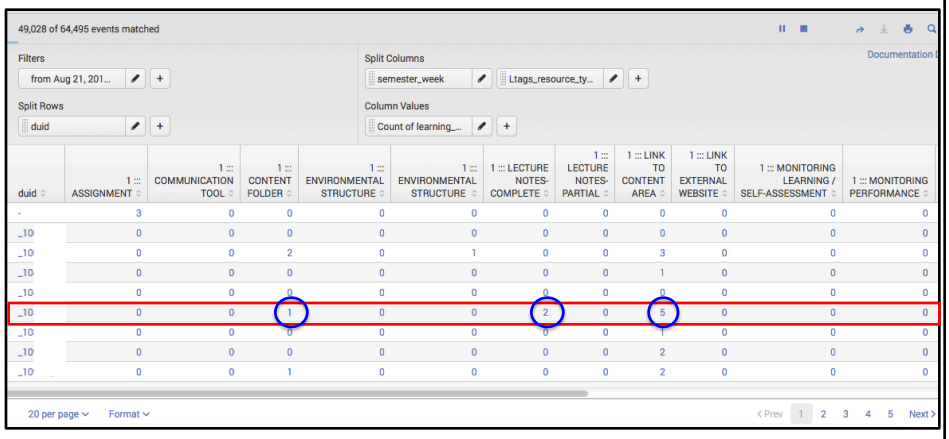
Study 1: Data Logging Infrastructure

- Organize it into tables; enrich it with meaningful information
  - Course information, user information, content information

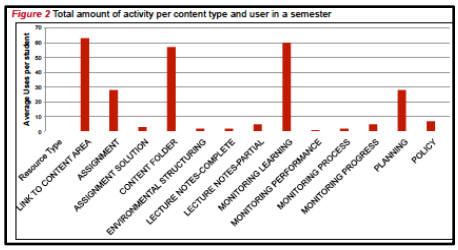


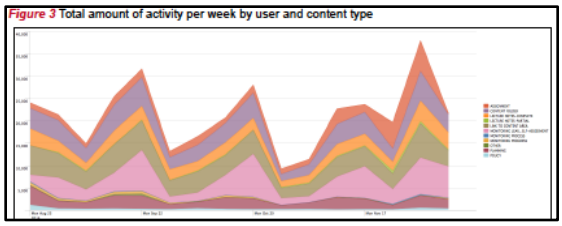
Study 1: Data Logging Infrastructure

- Restructure it to represent ***learning events***, based on the content students utilize.



Study 1: Data Logging





What Learning Behaviors are associated with achievement? *(EGG 101)*

		Semester Grade	Final Exam Grade
General Level of Engagement			
Content_FolderTotal	r	0.42	0.31
	p	0.00	0.00
Clicks on Links to Content	r	0.44	0.09
	p	0.00	0.37
Use of Instructor Provided Materials			
Complete Lecture Notes	r	0.39	0.37
	p	0.00	0.00
Partial Lecture Notes	r	0.37	0.04
	p	0.00	0.68
Assignments	r	0.25	0.25
	p	0.02	0.01
Assignment Solutions	r	0.05	0.13
	p	0.66	0.22
PlanningTotal	r	0.24	0.22
	p	0.02	0.04
PolicyTotal	r	0.06	0.00
	p	0.54	0.98
Use of LTAGs Products			
Self-Assessment Quizzes to monitor learning	r	0.20	-0.15
	p	0.06	0.16
Monitoring_progressTotal	r	0.00	-0.10
	p	0.98	0.34

Study 1: Implications

- Students use the resources provided.
- Certain resources are related to better outcomes.

Teaching students to use these resources well should improve outcomes…

Research Questions

- Can we improve student achievement if we teach them to use the resources instructors provide?

STUDY 2
TEACH STUDENTS HOW TO LEARN.

The Science of Learning to Learn

Rationale

- Providing students with resources is a start!
- Training them to use resources effectively should promote learning.

Training

3 modules

1. Learning Strategies
2. Managing Learning
3. Managing Behavior

The Science of Learning to Learn

Introduction

Emily… and her dilemma

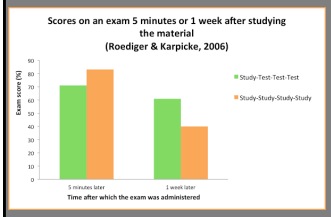
The realities of college, & the challenge

Instructional Approach

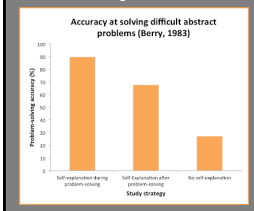
1. Learn about a learning strategy… And why it works
2. See how large an effect that strategy has had on college students' performance
3. Search for resources that help you use the strategy
4. Make plans for using the learning strategy in your course

Module 1: Learning Strategies

Self-testing

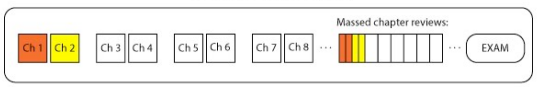


Self-Explanation

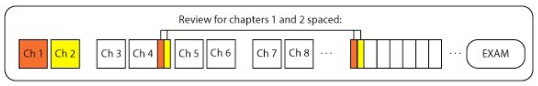


Spacing Practice

Usual study schedule:



Better study schedule:



Material	Week 1	Week 2	Week 3	
Chapter 1	Read chapter Attend Ch 1 lecture **self-test 3 times**	Self-test twice (Tuesday & Thursday)	Self-test once (Thursday)	Exam on Friday of Week 3
Chapter 2		Read chapter, Attend Ch 2 lecture, **self-test 3 times**	Self-test twice (Tuesday & Thursday)	
Chapter 3			Read chapter Attend Ch 3 lecture, **self-test 3 times**	

Module 2: Self-Regulating Learning

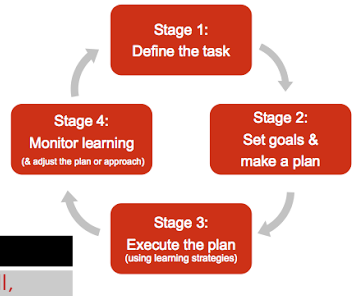
Consider Learning Objectives

The learning objective that appears in the syllabus:

By the end of this unit, students should be able to:
- Compare and contrast features of vertebrates and invertebrates.

How ***Emily*** read the learning objective:

vertebrates ... invertebrates.



Level of Understanding		Common verbs
1	**Knowledge**	Define, label, list, match, recall, recognize, name, identify
2	**Comprehension**	Explain, summarize, paraphrase, describe, compare, classify
3	**Application**	Apply, identify, solve, utilize, carry out, use, compute
4	**Analysis**	Analyze, categorize, examine, relate
5	**Synthesis**	Discuss, compose, combine, create, modify, develop
6	**Evaluation**	Appraise, choose, evaluate, judge, estimate, assess

Select Strategies, Monitor Learning, & Adapt!

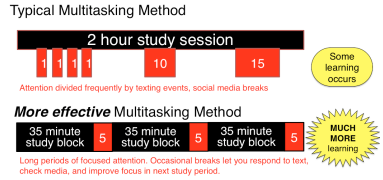
Module 3: Managing Behavior

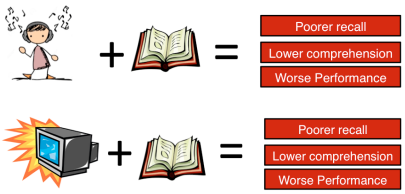
Set goals and make *implementation intentions* to help you stick to the plan.

SITUATIONAL CUE (If...,)	RESPONSE (then...)
"***If*** I am in a situation X,	***then*** I will do Y."

Keep perspective through Mental Contrasting

Avoid Distractions!





Method

Spring 2015

- Randomly assign 2 sections of Biology students
  - Learning to Learn
  - Extra Bio Content
- Provide resources via WebCampus
- Issue weekly announcements
  - (open, reminder, close)

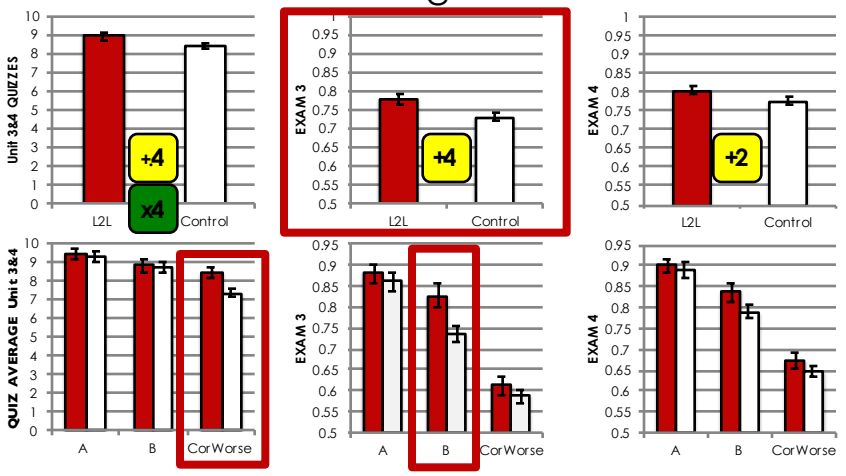
Fall 2015

- Replicate study in
  - BIOL 223
  - MATH 181
  - EGG 101
- Randomize students within a course using *adaptive release*.

Spring 2016

- Replicate with Math 124, continue in Math 181

Study 2: How does web-delivered training affect a student's learning skills & achievement?



Immediate Effects on Exam 3!

Practical Impact on Grades…

Effects for C earners on Quizzes; Sustained?

Study 2 Implications

- Student achievement can be increased by teaching them to use resources effectively.
- Not all students need this training.

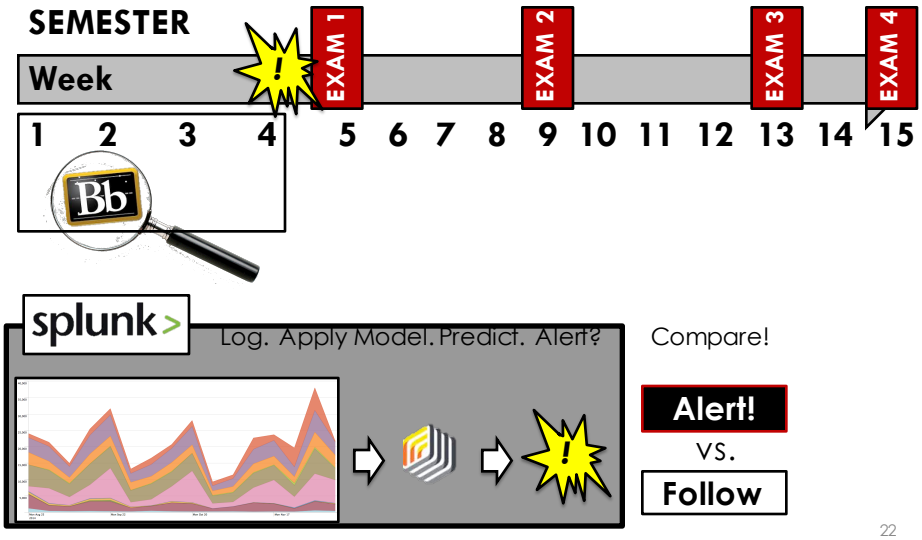
How do we identify those who need help learning, and how shall we help them?

Research Questions

- Can we identify students who are likely to perform poorly in a class?
- Can we help them?

STUDY 3
IDENTIFYING STRUGGLING STUDENTS … AND HELPING THEM TO LEARN

Study 3: Developing an early warning system



22

Study 3: Early Warning System Testing

- Build a prediction model looking at Fall 2014 data.
- Test Models built with Fall 2014 with Spring 2015 behaviors and Grades to ensure stability of predictions. Do it again with Fall 2015!

SUCCESS!
Fall 2014 model accurately predicts Spring 2015 grades!
AND Fall 2015!

	Predicted		
True	0	1	Out of
0	126	22	148
1	117	33	150
Out of	243	55	298

Model successfully recalls **85% of *C or Worse;*** 7 out of 8 who "need a message" get one.

We cast a wide net. Of predicted ***C or worse***, 48% earn a B or Better ("You can recover!").

An alert would be liberal; going to nearly all who need one, and to some who may recover on their own.

23

Study 3: Implementing the model

Predictor	B
Intercept	-0.42
Access Lecture Materials	
Total Clicks on link to Lecture Materials (count)	0.01
Week 2 accesses of Folder of Unit 1 Lecture Materials (count)	0.10
Access Chapter 2 Notes: Chemistry Macromolecules (any; dichot)	-0.52
Week 1 access of Chapter 4 Notes: Tissues Lecture1 (dichot)	1.81
Week 2 access of Chapter 4 Notes: Tissues Lecture1 (dichot)	0.59
Week 1 access of Chapter 11 Notes: Muscular system (dichot)	-0.49
Use of Self Assessment Tools	
Unit1SelfAssessmentQuizzesFolder (count)	0.07
Week 4 uses of Chapter3 Self-Assessment Quiz (count)	0.01
Use of Planning & Organization Resources	
Week 2 access of Ch 1 Review – Intro to AP Worksheet (dichot)	-0.78
Week 4 visits to course Calendar (count)	-1.53
Use of Additional Monitoring Tools	
Biology223LearningGoalsChapter43_count	-9.78

To produce a prediction
1. Report each action within a given time frame
2. data model pulls all these reports into a single table
3. An evaluation function that produces the prediction (z); applies it
4. *A threshold for selecting students to alert*

$$probability = \frac{1}{(1 + e^{-z})}$$

Plan is to pilot this in Biology in Spring 2016

WE HAVE A MODEL…
HOW SHALL WE USE IT?

A Check-in on your learning

Hi [Name]!

Our first course exam is coming up in a week or so.

[I'm a little concerned that you might not score so well because of the way you've been using the resources provided on WebCampus so far this semester.]

I want to check-in to make sure each student is on top of our content, learning in appropriate ways, and able to perform well. So, I'd like to direct you to **two** resources that can help you with learning the material in our course:

1. The first is a one-page summary of advice from students who have completed the couse in the past.
   These students each passed the course with an excellent grade, and they have shared some of the strategies that helped them perform well in the course.
2. A set of learning modules called "The Science of Learning to Learn."
   These modules describe learning strategies you can use with our course materials. Each has been shown to help college students learn in the past, and students who completed this training scored about 4 points better on their exams afterwards.

Both resources can be found on the WebCampus site for our course under the **STEM Learning Resources** link in the left panel (and provided in this announcement, below).

I hope you find that these resources help you to learn and perform well!
Dr. Utz

ADVICE FROM PAST STUDENTS ON

Tackling Anatomy & Physiology

UNLV students were asked to reflect on their experience learning in their anatomy and physiology lecture courses. Below they described the things that helped them learn and score well – and some that didn't.

Britney

Plan ahead! Seek out materials early on, make a study plan, and stick to it.

"There's definitely a learning curve in biology courses, so it's good to get advice from past students. I would recommend that students seek out any helpful materials in the beginning of the course and make a plan to use them. For courses like anatomy that require a lot of memorization, repeated practice is key. Certainly read the textbook, but then look to the learning objectives and the materials the instructor provides and plan from there – there are usually online tools like practice quizzes to help you study. Of course, studying last minute is the biggest mistake. Spacing out studying periods and making sure to never get behind is very important. Cramming is the worst thing to do and a big reason why finals can be so challenging.

I spent lots of time rehearsing my knowledge. Quizzing myself really help me learn factual information.

Alexis

"I've been most successful when I spend a lot of time rehearsing my knowledge. I usually make note cards as I read through the chapters and test myself using the note cards every week. This method is it requires time and dedication, but it works for helping me remember key definitions and concepts. Using note cards and online tools for quizzing myself has been great to help learn factual information. When it comes to learning systems and processes, I also do better when I read the chapter and then follow up by watching videos on the topic to help visualize and solidify the concept. Overall, it's the constant rehearsal that's been key for me."

Hermella

I learned tough concepts best when I explained them out loud to myself and to others.

"This class was hard, but I did manage to earn a B. For me, the first trick was to not procrastinate. I reviewed the material on a daily basis so that when a test got closer, all I had to do was review. This also gave me time to ask the teacher questions during office hours. Second, instead of reading only the textbook, I focused on my notes & slides when practicing the material. If there was something I didn't understand, I went back to the book, but it was too dense to re-read as a main study method. Finally, although I personally don't like studying in a group, it was helpful for anatomy and physiology as there is a lot to explain. I found that I retain the information better when I explained it out loud to someone else."

I used the syllabus and study guides to figure out what to know, and how well to know it.

John

"There is a tremendous amount of material in a lecture course like [Anatomy and Physiology]. That makes it really hard to know what topics to study and how well you need to know them. Eventually, I figured out that it was all right there when I looked at the syllabus – the lists of learning objectives told me exactly what content I needed to focus on, and whether I needed to be able to just name or identify something, or whether I needed to be able to describe or explain it. Once I figured this out, I was able to study really well for tests, and it helped a lot.

Thoughts from an Educational Researcher — **Matt Bernacki, PhD** *UNLV College of Education*

These students provide great advice…
… their methods helped them learn, and earn As & Bs in biology courses here at UNLV.
… the strategies they suggest match what we know about learning – planning, practice quizzing and self-explanation are known to be effective learning strategies
I hope you can make use of their advice, learn the material, and earn the grade you want!

Learning to Learn Modules

Emily's dilemma

Realities of college life

As you've recently learned, there are two important realities that college students face:

#1 College students need to pursue many important goals at once.

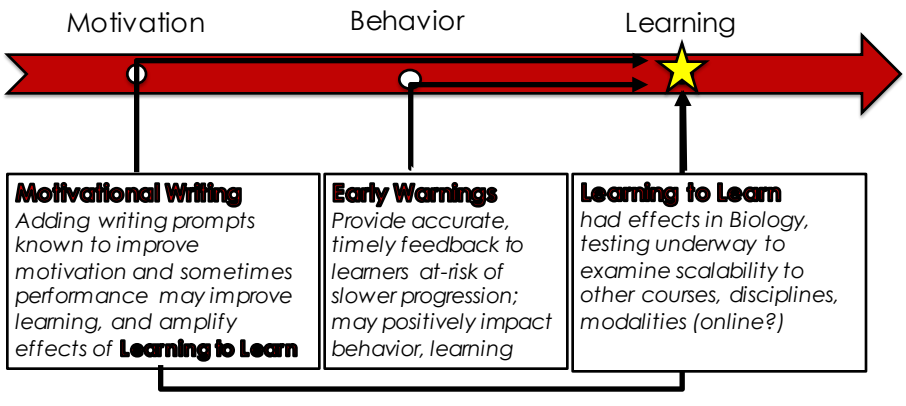
#2 College courses are much more challenging than high school courses.

Module 1: *Effective Learning Strategies*	Module 2: *Regulating the Learning Process*	Module 3: *Regulating your Learning Environment*
Self-Testing	Interpreting a Courses' Learning Objectives	Mental Contrasting
Spacing Study Activities	Setting Good Goals	Implementation Intentions
Self-Explanation	Making A Plan	Avoiding Distractions
	Engaging in Learning	
	Monitoring Learning	
	Adapting Your Approach	

28

STAY TUNED…

Prospects for improving STEM Learning



Combination of Learning Theory + Analytic Approaches makes for a powerful tool kit. The tools need to be continually sharpened, but their potential is immense.

30

THANKS…

… to UNLV collaborators  +

… project advisors  +

… to NSF & UNLV OIT, University Programs for Support

… For your attention

And your questions & ideas?

31

Can Learning to Learn trainings benefit your students?

How can reports on student activity help faculty?

Can we build standardized, digital resources for FY/SY faculty to use?

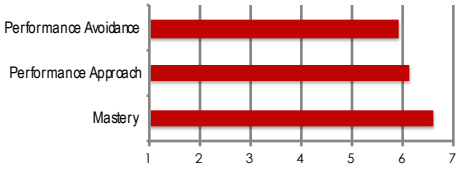
?

How can ***learning theory*** or ***learning analytics*** help students master **University Undergraduate Learning Objectives**?

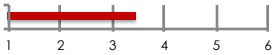
- understand and integrate disciplinary principles
- develop skills & desire for lifelong learning
- use research & reason to critically analyze problems
- write and speak effectively
- know and respond to diverse perspectives justly as active citizens

How motivated are UNLV students to learn?

Goals

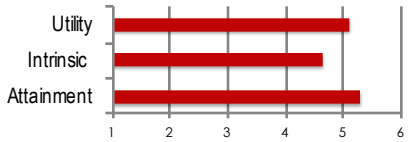


Academic Anxiety

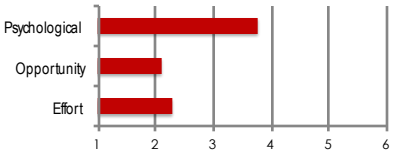


Perceptions of Stereotype Threat

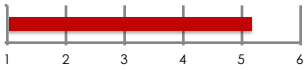
Perceived Value



Perceived Cost



Efficacy



33

How do these motivations relate to achievement and retention?

Type of Motivation	Semester Grade	Intention to Leave (Oct)	Intention to Leave (Dec)
Mastery Goals	0.14	**-.32**	-0.14
Performance Approach Goals	-0.02	-0.04	-0.04
Performance Avoidance Goals	**-.19**	-0.01	0.13
Efficacy	0.13	**-.28**	**-.22**
Attainment Value	0.02	**-.21**	-0.08
Intrinsic Value	0.01	**-.30**	**-.22**
Utility Value	0.07	**-.25**	-0.12
Effort Cost	-0.08	**.30**	**.27**
Opportunity Cost	-0.01	0.14	-0.04
Psychological Cost	-0.08	0.10	0.10
Stereotype Threat	-0.04	0.15	0.09
Academic Anxiety	-0.12	0.14	0.12

34

Progress Report

- **Study 1: Completed Fall 2014**
  - EGG 101 (Introduction to Engineering)
  - BIOL 223 (Anatomy & Physiology I)
  - MATH 181 (Calculus I)
- **Study 2: Ongoing**
  - Complete twice in BIOL 223
  - Data collection ongoing n MATH, EGG
- **Study 3: Launches 2/15 in BIOL [Uses S1 data]**
  - Prediction model built Summer 2015
  - Model confirmed Fall 2015
  - Piloting in BIOLOGY February 15
    - "early warning" message to students
    - Resources to help them learn