Learning Theory and Analytics as Guides to Improving Undergrad STEM Education

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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.
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

- Restructure it to represent learning events, based on the content students utilize.
What Learning Behaviors are associated with achievement? (EGG 101)

<table>
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<th>Final Exam Grade</th>
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<td>p 0.00</td>
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</tr>
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<td>0.09</td>
</tr>
<tr>
<td></td>
<td>p 0.00</td>
<td>0.37</td>
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</tbody>
</table>

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 0.46         | 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 0.34         | 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

Scores on an exam 3 minutes or 1 week after studying the material (Kanigel & Kringel, 2006)

Spacing Practice

Usual study schedule:

Better study schedule:

Module 2: Self-Regulating Learning

Consider Learning Objectives

The learning objective that appears in the syllabus:

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

Select Strategies, Monitor Learning, & Adapt!
Module 3: Managing Behavior

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

Keep perspective through Mental Contrasting

Avoid Distractions!

Typical Multitasking Method

- 2-hour study session
- 30 minutes of learning
- 15 minutes of social activities
- Poor recall
- Lower comprehension
- Worse Performance

More effective Multitasking Method

- 3-hour study session
- 30 minutes of learning
- 5 minutes of social activities
- Better recall
- Higher comprehension
- Better Performance

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?

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**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
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!**

<table>
<thead>
<tr>
<th>Predicted</th>
<th>True</th>
<th>0</th>
<th>1</th>
<th>Out of</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>126</td>
<td>22</td>
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<tr>
<td></td>
<td></td>
<td>1</td>
<td>117</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Out of</td>
<td>243</td>
<td>55</td>
<td>298</td>
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</table>

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.

Study 3: Implementing the model

<table>
<thead>
<tr>
<th>Predictor</th>
<th>B</th>
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<tr>
<td>Intercept</td>
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<tr>
<td>Access Lecture Materials</td>
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</tr>
<tr>
<td>Total Clicks on link to Lecture Materials (count)</td>
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</tr>
<tr>
<td>Week 2 accesses of Folder of Unit 1 Lecture Materials (count)</td>
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</tr>
<tr>
<td>Access Chapter 2 Notes: Chemistry Macromolecules (any; dichot)</td>
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<tr>
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<tr>
<td>Week 1 access of Chapter 11 Notes: Muscular system (dichot)</td>
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<tr>
<td>Use of Self Assessment Tools</td>
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<tr>
<td>Unit1SelfAssessmentQuizzesFolder (count)</td>
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<tr>
<td>Use of Planning &amp; Organization Resources</td>
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<tr>
<td>Use of Additional Monitoring Tools</td>
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<tr>
<td>Biology223LearningGoalsChapter43_count</td>
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</table>

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 [2]; applies it
4. A threshold for selecting students to alert

\[
\text{probability} = \frac{1}{(1 + e^{-z})}
\]

Plan is to pilot this in Biology in Spring 2016
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 course 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.

**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, repeat practice is key. Certainly read the textbook, but there are lots of learning objectives and thematic chapters 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 you never get behind is very important. Cramming is the worst thing to do; it’s a reason why finals can be so challenging.”

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**Britney**

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

> “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 these cards every week. This method is time consuming and laborious, but it works for me.”

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**Alexis**

**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 C. 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 textbook, but I 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.”

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**Hermella**

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

> “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 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/identify something, or whether I needed to be able to describe or explain it. Once figured out, I was able to study really well for tests, and it helped a lot.”

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**John**

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Thoughts from an Educational Researcher

Matt Bernacki, PhD, UNLV College of Education

> “These strategies provide advice... they are methods that some students find helpful to learn and earn As & Bs in biology courses here at UNLV.”

> “...these strategies, when used together, can be successful learning strategies for students.”

> “I hope you can make use of these ideas to learn the material, and earn the grades you want.”

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Learning to Learn Modules

**Module 1: Effective Learning Strategies**
- Self-Testing
- Spacing Study Activities
- Self-Explanation

**Module 2: Regulating the Learning Process**
- Interpreting a Course’s Learning Objectives
- Setting Good Goals
- Making A Plan
- Engaging in Learning
- Monitoring Learning
- Adapting Your Approach

**Module 3: Regulating your Learning Environment**
- Mental Contrasting
- Implementation Intentions
- Avoiding Distractions

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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.

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Prospects for improving STEM Learning

Motivation  Behavior  Learning

**Motivational Writing**
Adding writing prompts known to improve motivation and sometimes performance may improve learning, and amplify effects of Learning to Learn.

**Early Warnings**
Provide accurate, timely feedback to learners at-risk of slower progression; may positively impact behavior, learning.

**Learning to Learn**
Had effects in Biology, testing underway to examine scalability to other courses, disciplines, modalities (online?)

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

... to UNLV collaborators
... project advisors
... to NSF & UNLV OIT, University Programs for Support
... For your attention **And your questions & ideas?**

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**Can Learning to Learn trainings benefit your students?**

**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

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**Can we build standardized, digital resources for FY/SY faculty to use?**
How motivated are UNLV students to learn?

Goals
- Performance Avoidance
- Performance Approach
- Mastery

Perceived Value
- Utility
- Intrinsic
- Attainment

Efficacy

Academic Anxiety
- Perceptions of Stereotype Threat
- Psychological Cost
- Effort

How do these motivations relate to achievement and retention?

<table>
<thead>
<tr>
<th>Type of Motivation</th>
<th>Semester Grade</th>
<th>Intention to Leave (Oct)</th>
<th>Intention to Leave (Dec)</th>
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</thead>
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<td>-0.14</td>
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<tr>
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<td>-0.04</td>
<td>-0.04</td>
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<tr>
<td>Performance Avoidance Goals</td>
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<tr>
<td>Efficacy</td>
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<td>0.14</td>
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</table>
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 in 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