BETTER THAN EXPECTED

Using Learning Analytics to Promote Student Success in Gateway Science

By Mary C. Wright, Timothy McKay, Chad Hershock, Kate Miller, and Jared Tritz

Learning Analytics (LA) has been identified as one of the top technology trends in higher education today (Johnson et al., 2013). LA is based on the idea that datasets generated through normal administrative, teaching, or learning activities—such as registrar data or interactions with learning management systems—can be analyzed to enhance student learning, academic progress, and teaching practice.

Examples of LA projects in colleges and universities include Purdue University's "Course Signals" system, an early-alert notification for struggling students, and Austin Peay State University's "Degree Compass," a course recommender program based on predictive analytics.

Useful Weblinks about Learning Analytics

EDUCAUSE. (2011). *7 things you should know about first-generation learning analytics*. Boulder, CO: Author. Available at http://www.educause.edu/Resources/7ThingsYouShouldKnowAboutFirst/242966

US Department of Education. (2012, October). *Enhancing teaching and learning through educational data mining and learning analytics: An issue brief*. Available at http://www.ed.gov/edblogs/technology/files/2012/03/edm-la-brief.pdf

Society for Learning Analytics Research (SoLAR): http://www.solaresearch.org/

Sample initiatives:

Purdue Signals Project: http://www.itap.purdue.edu/learning/tools/signals/

Carnegie Mellon Open Learning Initiative: http://oli.cmu.edu/get-to-know-oli/course-features/

Austin Peay State University's Degree Compass: http://www.apsu.edu/information-technology/degree-compass-what

University of Michigan, Department of Physics, E^{2}Coach: http://sitemaker.umich.edu/ecoach/home

Although the promise of LA is great, key areas of the approach have been identified as needing to be better realized (Dringus, 2012). The key challenge is utilizing large data analyses for actionable and effective interventions in the classroom—that is, enabling "faculty to more precisely identify student learning needs and tailor instruction appropriately" (Johnson, et al., 2011, p. 28).

Here, we describe one large-scale LA initiative at the University of Michigan (U-M) to improve performance for thousands of students in gateway physics courses. Our goal is not only to describe the development and implementation of this unique initiative in STEM education but also to discuss how the approach we used can help meet some of the challenges to more widespread LA adoption.

To foster student success in gateway physics at U-M, we engaged in a four-step process. The approach involved a large data analysis of course records, exploratory interviews to better understand student performance, surveys of students to gather their narratives, and the development of a personalized learning tool. We wanted to develop a rich, student-centered picture of effective strategies in introductory physics.

The project involved collaboration between multiple units on campus:

- The Department of Physics
- The Center for Research on Learning and Teaching, U-M's teaching center
- The Science Learning Center, an academic study support office
- The Center for Health Communications Research, which develops tailored health-communications strategies.

We needed to call upon many experts to develop E^{2}Coach (an Expert Electronic Coach), a computer-tailored student support system for gateway STEM courses.

Helping Students Succeed in Gateway Courses

This work first focused on students enrolled in two large introductory physics sequences at U-M. Physics 135 and 235 are intended for life science students, many of whom do not see the need for physics in their programs. Physics 140 and 240 are aimed at physical science and engineering students, who are much more likely to recognize physics as important to their core educational and career goals.

Both sequences are large, enrolling a total of 1900 students per term. Grades in all of these courses are based on online homework, three midterm examinations, in-class peer-instruction questions, and a final.

The challenges to student success in introductory physics are well documented. They include perceptions of the inaccessibility of material, misconceptions that students bring to class, the diversity of student preparation, and a misalignment between student and instructor goals. Failure to thrive in these courses has important implications, including a negative impact on STEM persistence, especially for women and underrepresented minorities.

Physicists have tried hard to improve student learning and retention in physics. They have done pioneering work in active-learning strategies, improved lecture demonstrations, and adopted non-cognitive approaches such as values affirmations (e.g., Mazur, 1996, and Miyake et al., 2010). These interventions are generally employed classroom-wide, with all students receiving identical treatment.

We took on these challenges in a different way. One novel aspect of our project is the development and delivery of highly personalized learning support on large scales. Using interviews and surveys, we collected successful strategies from a diverse array of former students. Current students then receive advice from former students who resemble them in salient ways, including preparation for physics, sense of self-efficacy, gender, and career plans.

Tailoring like this has been found effective in many contexts, since it avoids students' tendency to ignore advice they do not consider personally relevant. Ost (2010) adds that students at risk of abandoning the physical sciences are most influenced by their peers, a finding that is true in other disciplines as well.

Step 1: Predicting Student Performance

To develop a predictive model of student performance, faculty in the Department of Physics first collected administrative data describing the background and progress of 48,579 students through introductory physics courses at U-M over 14 years. These data combine detailed information about each student upon his or her arrival in the class—including standardized test scores, high school and prior U-M GPAs, socioeconomic status, and gender— with a full portrait of the student's progress through the course, including homework grades, classroom participation, exam scores, and final grades. Using methods from the discipline of physics—albeit typically applied to cosmology rather than to registrar data—faculty conducted analyses to better understand key predictors of final course grades.

Rather than rely on an *absolute* approach to measures of student performance, such as the final course grade, this analysis used a *relative* estimate of student performance—whether a student performed *better* or *worse than expected* (BTE or WTE). Expected performance—which has been shown to play a key role in motivation and achievement—is derived from incoming characteristics such as prior GPA and standardized test scores. In this approach, a student receiving a C in physics might be considered BTE if peers with a similar background typically fail. Likewise, a student with a 4.0 GPA receiving her first B+ (which others might consider a good grade) would be considered WTE.

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Not surprisingly, prior U-M GPA was the primary predictor of a student's grade in introductory physics. However, even controlling for background and prior performance, there was a problematic gender dynamic. In general, female students performed worse than expected, falling a quarter of a letter grade below male students after adjusting for all measures of incoming preparation: SAT or ACT math score, high school GPA, and prior GPA (Miller, 2011). Unfortunately, these results are consistent with those seen in other US institutions (Kost, Pollack, & Finkelstein, 2009).

Although this data analysis presented a general picture of student performance in gateway physics, the quantitative learning-analytics model could not tell us what students who performed BTE did differently from those with a WTE final grade. To explore this question, staff in the Center for Research on Learning and Teaching interviewed students who had recently completed the introductory physics courses.

Step 2: Student Interviews

After receiving approval from our university's human subjects review board, grade predictions allowed us to invite students whose performance was at the most extreme ends of the BTE and WTE categories. In our interviews, we focused on understanding students' experiences of the classes, their recommendations for pedagogical changes, and their use of strategies identified by prior literature as conducive to academic success. These included social assistance-seeking; goal setting and planning; reviews of class materials; and the organization/rearrangement of instructional materials by, for instance, making outlines or taking notes.

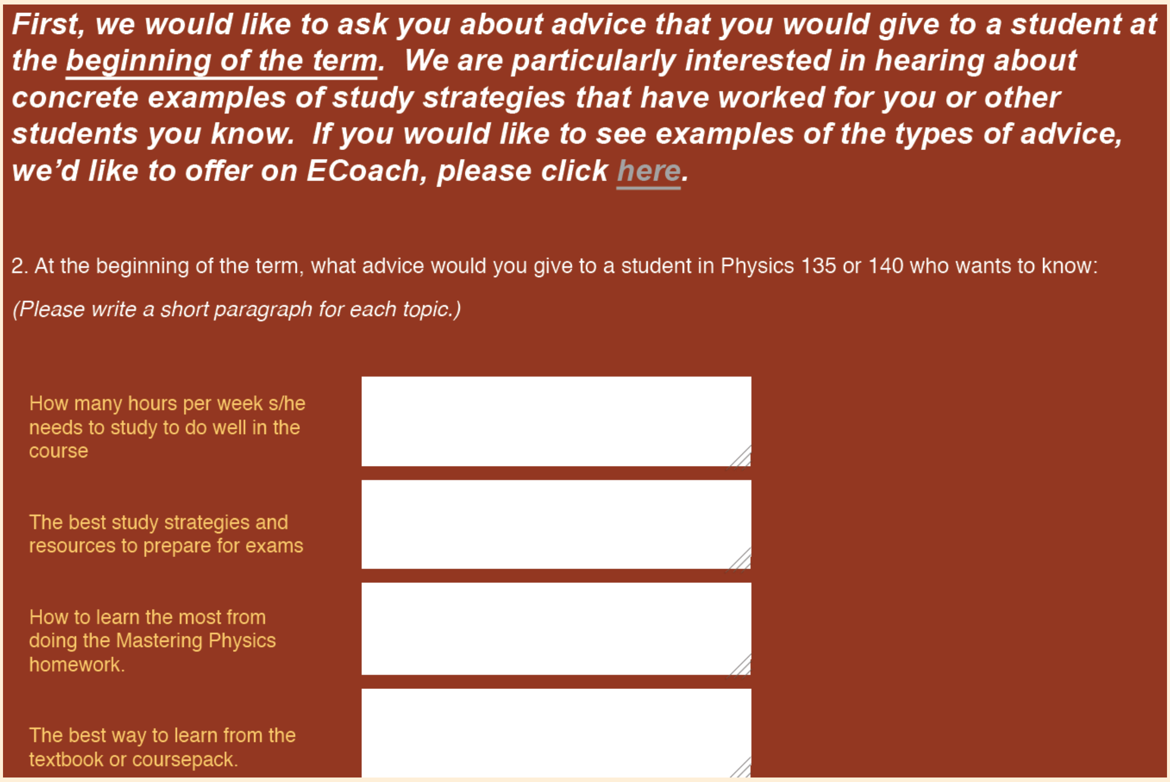
A key challenge of the project was recruiting students for the interviews – especially given that students' physics grades were generally lower than their performance in other classes. After 170 email interview requests, 19 students participated; over half (58 percent) of the interviewees were female. Nine participants were BTE, and 10 were WTE. Because these interviews were exploratory—primarily to develop a survey—we moved forward with them and did hear some rich narratives.

In nearly all cases (17/19), student perception of expected course performance aligned with our analysis: Most WTE students reported that they had scored "a little worse" or "a little lower" than hoped, while the BTE group noted that they had performed as well or better than they had anticipated. The two exceptions were students whose grades were at the boundary of the BTE/WTE categories, who expressed conflicted self-assessments. For example, a female WTE student who had received a B+ (the highest grade among WTE students) initially said she did "better than I expected." However, later in the interview, she noted that, since she had anticipated being a physics major, she was not "happy with" her performance.

When we analyzed the interviews, we found a few key differences in the strategies used by the students who performed BTE and WTE, which we summarize briefly here:

1. BTE students tended to be more adaptive than WTE ones in their study habits. Interestingly, reported time for non-exam weeks was about the same for both groups of students, but BTE students reported studying 5–10 hours more during exam weeks.

Figure 1. Sample Student Survey Block



First, we would like to ask you about advice that you would give to a student at the beginning of the term. We are particularly interested in hearing about concrete examples of study strategies that have worked for you or other students you know. If you would like to see examples of the types of advice, we'd like to offer on ECoach, please click here.

2. At the beginning of the term, what advice would you give to a student in Physics 135 or 140 who wants to know:

(Please write a short paragraph for each topic.)

How many hours per week s/he needs to study to do well in the course

The best study strategies and resources to prepare for exams

How to learn the most from doing the Mastering Physics homework.

The best way to learn from the textbook or coursepack.

2. BTE students also made more adjustments in response to exam feedback. While all students described struggling with the first exam, BTE students reported that afterwards, they increased the number of ways they studied (e.g., doing more practice problems). In contrast, more than half of WTE students reported dropping a resource, most frequently discontinuing the use of the textbook or coursepack.
3. While BTE students more frequently reported studying with other students, WTE students more commonly indicated that they went to the "Physics Help Room," a space in which instructors, graduate students, and undergraduate teaching assistants answer questions from any student in any physics course. It may be that relying too much on expert assistance hindered the WTE students' ability to solve problems on their own. It may also be that Help Room staff (largely graduate students and undergraduates) receive no special training, while the Science Learning Center (SLC) trains the leaders for the nearly 600 peer-led study groups supporting a variety of introductory science courses.

Although these findings are generally consistent with those in the science of learning and science education, the interviews also gave us a more nuanced understanding about how these dynamics played out in the context of U-M physics courses. More importantly, they generated transcripts of student advice about their physics experience, which allowed us to pull quotes that could be relayed to other students and to craft a survey to elicit more student advice.

Step 3: Surveys of Peer Study Group Leaders

To amplify the findings from the BTE/WTE interviews, Center for Research on Learning and Teaching staff created a survey for the larger group of students who had served as study group leaders in the SLC. To be a leader, students must have received at least a B+ in the course in which they serve. In fall 2011 and winter 2012, we invited all SLC study group leaders who had taken Physics 135 or 140 to complete a survey.

The key purpose of these surveys was to elicit quotations about themes identified in the BTE/WTE interviews. For example, adaptive time and resource usage differentiated BTE and WTE students, so open-ended survey questions asked about study-time and resource-use strategies at the beginning and end of the term (see Figure 1).

To allow us to provide tailored advice, survey respondents were asked to report a variety of background characteristics, such as their major, career and educational plans, college math background, and high school physics background. They were also asked whether we should share their advice anonymously or with their first name and a picture, so that students might know the source of their advice. Of the survey respondents, 42 percent wanted their advice used anonymously, 58 percent said we could use their name, and 40 percent said we could use their photograph with the advice.

These surveys generated a rich set of responses to complement the interview data. Although the responses differed slightly, most of the student advice was relatively consistent. For example, one female engineering student who remembered being "very confident" that she would receive the grade she wanted advised her peers to

> work with others. It is amazing how someone can approach a problem completely differently. There is more than one right way, and one way may fit your brain better than another. Also, TEACHING is a good way to more thoroughly understand something. ... Join a study group, where you'll be in a peer group situation to implement both of these study strategies.

A male pre-medical student in a life science major who took physics in high school but was only "somewhat confident" that he would receive the grade he wanted recommended, "If you think changing study methods will help, try the new methods out. Practice exams will gauge whether your new methods are working."

Finally, a male math major with plans to work as a business consultant and no high school physics background suggested, "They should talk with their classmates about what their study strategies are. They could also join a study group."

Step 4: E^{2}Coach Development

The knowledge gained from BTE and WTE student interviews, combined with quotes gleaned from study-group leader surveys, provided us with a rich suite of advice for students taking these courses. To deliver tailored advice, Department of Physics faculty and staff developed E^{2}Coach.

E^{2}Coach is based on the Center for Health Communications Research's open-source computer-tailored intervention system, typically used for public-health interventions such as smoking cessation. Through this collaboration between physics and public health faculty and staff, an intervention was developed that offers a tailored study support system, customized by prior course-performance data, students' responses to surveys about their backgrounds and goals, and ongoing physics assessment information.

> **"Open-ended survey questions asked about study-time and resource-use strategies at the beginning and end of the term.**

FIGURE 2. SAMPLE E2COACH PAGE

Hello Kate!

Welcome to your ECoach site. We'll be here every step of the way to help you work towards your goal of succeeding in Physics 240.

It's especially important for you to do well because you'll use physics as a Chemical Engineering major. As an engineer, you may have people's lives in your hands. They'll be counting on you to get the physics right when you design a steering mechanism, a bridge, or a replacement hip. Being a responsible professional starts here!

You can turn to us for advice about using your study time effectively, the best approaches to studying for exams, and available resources to you.

You told us that the grade you want to receive is a B. This is a good goal for you— you should be more confident that you can achieve this! We think you can! In fact, we've seen students come in unsure about their success and receive a B that you want. However, you should know that confidence does matter! We want you to go into each exam sure that you can do well! What if you aim for an even higher grade? Keeping in mind that you're usually an A student with a GPA of 3.6, come up with a new, higher goal that will push you to do even better. ECoach will be here every step of the way to help you as you embark on this goal.

Where Does Physics Fit?

You told us that you value relationships with family and friends, learning and gaining knowledge and sense of humor. You also reported that you are involved with student clubs or organizations. This is on top of the work associated with your other classes. There *is* a way to make physics fit into this mix. Let's figure out what works for you.

We see that you have many strengths coming into this class. Some of the most important are:

- You're already in your second semester of physics in college—you understand what's expected of you
- You're prepared to spend 12 hours per week preparing for class, working on homework and studying
- Physics is applicable to your everyday life—there are examples all around you

There are also some factors that could be potential challenges for you. These may include:

- Physics is a difficult subject for anyone to master
- You said that you're not taking this course because you're interested—hopefully you'll find a topic that you find exciting
- You don't know anyone else in this class yet

You should know that lots of people come in with these challenges and do great. ECoach will draw on this knowledge of your strengths and weaknesses to recommend study techniques that are tailored to your specific needs. If you follow this advice and put in a lot of hard work, you can do well in this course too!

At the beginning of the term, students enrolled in an introductory physics course receive an email from E^{2}Coach with information about the intent of the project and instructions about how to opt into the system (see Figure 2).

If students choose to utilize E^{2}Coach, they complete a short initial survey about their confidence and goals as related to their upcoming physics course. One week into the course, they receive their first customized message, complete with advice on how to approach the class, quotes from previous students about how best to study, and links to additional resources. Additional tailored messages are delivered every few weeks through the term, preparing them for the first exam, responding to their performance on it, and even responding to their final performance with advice for the future.

Advice offered addresses test-taking skills, motivation, and the need to adapt learning approaches in response to performance. E^{2}Coach suggests how frequently the student should use learning resources and provides detailed feedback about his or her current status, both absolute and in reference to the desired grade. E^{2}Coach also provides normative information, allowing students to see what students who achieved their desired grade in previous terms did to succeed and to understand how well they would have to do on future tests in order to receive that grade.

This multi-pronged approach was informed by research on college learning-skills programs, which recommend a range of "cognitive, metacognitive, and motivational strategies in order that students will have both the 'skill' and the 'will' to use the strategies properly" (Hofer et al., 1998, p. 60).

IMPACT

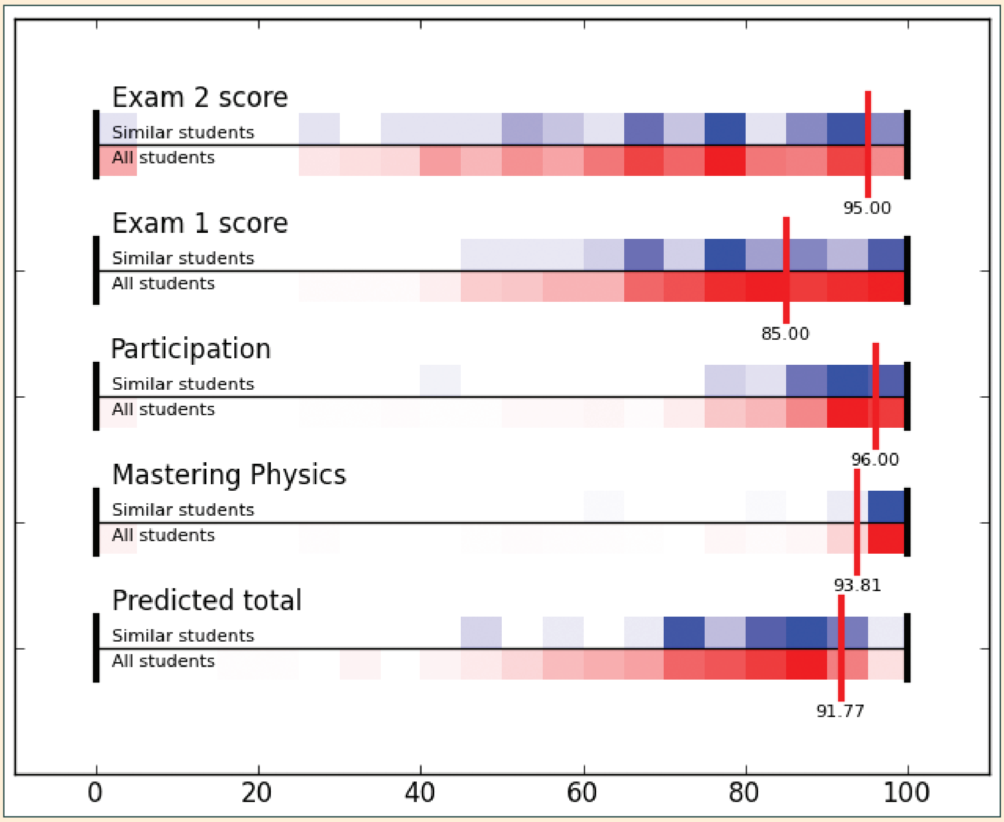
E^{2}Coach was launched in January 2012 and offered support to over 3,000 students during its first year. Initial data show that students who used the system performed better than expected significantly more often than those who did not.

To evaluate the system, we first computed a "BTE score," comparing expectations based on predictors to actual physics grade and computing the difference. We also measured how frequently students accessed E^{2}Coach, if they did so at all. These frequencies were categorized into the following groups: non-users, low users (who accessed E^{2}Coach two or fewer weeks per term), moderate users (three or four weeks), and high users (five or more weeks).

Then we examined BTE scores for each group, and we found that usage significantly predicted BTE scores for the groups ($p < .001$). On average, high users had a BTE score

> **"Advice offered addresses test-taking skills, motivation, and the need to adapt learning approaches in response to performance.**

Figure 3. Performance Feedback Display Provided to Students



of 0.17 (i.e., 0.17 grade points above their predicted incoming GPA), while non-users showed no difference, with a BTE of 0.0.

Given that gender dynamics was one motivating concern in the development of E^{2}Coach, it is important to note that a majority of high (52.2 percent) and moderate (51.0 percent) users were women, while most low (58.5 percent) and non-users (72.9 percent) were men. However, while female students who were moderate or high users of the system scored significantly higher than non- or low-using female students, they still scored lower than their male peers. This is clearly a finding that we need to pursue in future iterations of E^{2}Coach, but it may be that even good study-support systems have their limits in addressing more profound cultural and structural classroom challenges. It is notable that the university is beginning to engage in an NSF grant project that more broadly addresses gender disparities—i.e., women performing worse than expected—in several introductory STEM courses.

Making Learning Analytics Work for Learning

Learning analytics has great potential to reshape the college classroom and to improve student achievement. However, the enterprise also faces significant challenges. The E^{2}Coach project at U-M may offer some strategies to more fully realize LA's potential to improve college-level learning by using large-scale data analyses to change the student experience.

1. LA work "generally falls within the purview of IT departments" (Johnson, et al., 2011, p. 28). However, the expertise and buy-in of multiple collaborators across campus is critical, as is starting the project from the faculty's learning goals. Initiated because of a faculty teaching concern, the development of E^{2}Coach required multidisciplinary and cross-institutional perspectives on the problem, drawing upon campus-technology, educational-development, learning-center, and evaluation resources.
2. LA projects often are *data driven*, oriented around the possibilities of large datasets to reveal new information (Dyckhoff et al., 2013). But our approach was instead *question-driven*, framed around questions that instructors raised in relation to a practical teaching and learning problem. Large-scale quantitative analyses of the type typically used for LA projects were utilized here, but small-scale qualitative work also was necessary to develop intervention strategies.
3. Student privacy concerns also have been identified as another possible limitation of LA (Greller & Drachsler, 2012). Although human subjects review may not be appropriate or necessary for every LA project, that review was helpful for thinking through ethical issues and led to greater transparency to student participants in this project.
4. Acting on individual LA results for students requires the ability to personalize interactions at scale. E^{2}Coach enabled us to speak individually to students in a manner informed by their backgrounds, status, and goals. It

> “It may be that even good study-support systems have their limits in addressing more profound cultural and structural classroom challenges.

is a good example of the ways in which technology can personalize education but also of the ways in which even good learning-analytics systems may have their limits in addressing more profound teaching and learning challenges.

As of fall 2013, E^2Coach will be extended to other gateway STEM courses at U-M, thereby serving over 8,000 students per term. Using LA to improve student performance in class promises to help more students perform better than expected in gateway science courses at U-M. Further, we suggest that through multidisciplinary, cross-institutional collaborations and a question-driven approach, the promise of LA to improve the student experience can be better realized.

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