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Research notes

Improving students' performance in quantitative courses: The case of academic motivation and predictive analytics

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A B S T R A C T

This 5 years longitudinal study explores and tests the effect of the combined use of some principles from the motivation achievement theories of educational psychology and predictive analytics (pedagogical innovation) on enhancing students' academic self-monitoring, engagement, and performance in a junior level quantitative business course. If and when unsatisfied with their class performance, or their predicted grade and likelihood of success of the pedagogical innovation, students in the post-innovation group were directed to either self-regulate their class engagement, and/or seek the intervention of the instructor for remedies to facilitate their success. Results show the post-innovation group outperforming the pre-innovation group with more As (+43%), Bs (+35%), with fewer Cs (−20%) supporting the hypothesis that the suggested innovation significantly improved students' performance. However, no significant improvement in the failure rate of the at-risk students (DFWs) was observed. While most students with high predicted probability of passing were able to self-regulate their academic engagement, only few of the at-risk students sought the intervention of the instructor, with the majority eventually succeeding in passing the course (some after several trials) due to their improved class engagement, and their perceptions of the instructor's positive role in facilitating their success.

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1. Introduction

Students' negative attitude and anxiety toward mathematics and their far reaching implications on their academic performance and career opportunities are well documented in the literature (Bessant, 1995; Meece, Wigfield, & Eccles, 1990; Wigfield & Meece, 1988). With only 26% of graduating high school students meeting the minimum ACT College Readiness Benchmark[1] in all testing subject matters, e.g., English, Algebra, Social Science, and Biology (ACT, 2013), higher education institutions have been prompted to develop interventions strategies to facilitate learning, and guide their students toward continually improving their academic performance (Handel, 2009).

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[1] The Benchmarks are scores on the ACT subject-area tests that represent the level of achievement required for students to have a 50% chance of obtaining a B or higher or about a 75% chance of obtaining a C or higher in corresponding credit-bearing first-year college courses. http://www.act.org/solutions/college-career-readiness/college-readiness-benchmarks/.

1.1. Literature review

Educational psychologists assert that most human actions are thought to be goal-directed toward either achieving desired outcomes or avoiding dreaded ones (Bandura, 1986). As such, this study posits that the combined use of motivation achievement theories and predictive analytics (pedagogical innovation), will facilitate students' academic self-monitoring and self-regulation, and assist in linking current actions to future goals for the purpose of improving their academic performance.

Although several definitions exist for academic engagement, this research adopts Kuh's and Hu's view which defines academic engagement as the "quality of effort students devote to educationally focused activities that contribute directly to desired outcomes" (Kuh & Hu, 2001). It is a multi-dimensional construct involving students' emotion, behavior, and cognition (Fredrick, Blumenfield, & Paris, 2004), and a robust predictor of students' learning, test scores, retention, and graduation (Appleton, Christenson, & Furlong, 2008; Patrick, Ryan, & Kaplan, 2007; Skinner & Pitzer, 2012). Students who were positively engaged in their course work and with instructors tend to be highly motivated (Ryan & Deci, 2009), are able to develop a better perspective about their academic progress and achievements (Finn & Zimmer, 2012; Fredricks et al., 2004), tend to score higher grades (Astin, 1993; Darling-Hammond, 1997; Kuh, 2003; Roderick & Engel, 2001), and experience lower drop-out rates (Croninger & Lee, 2001; Mangum, Baugher, Winch, & Varanelli, 2005). In contrast, unmotivated and disengaged students are at risk of lower performance and dissatisfaction which might lead to academic failure (Curwin, 2010; Willingham, Pollack, & Lewis, 2002; Uekawa, Borman, & Lee, 2007), and students' dropout (Bridgeland, Dilulio, & Morision, 2006). Hence, educators are expected to motivate students to help them achieve their educational goals (Miller & Brickman, 2004), and to self-monitor and self-regulate their own progress (Ames, 1992; Brophy, 2010; Covington, 1992).

Self-monitoring is the act of observing and recording one's own behaviors (Hallahan, Kauffman, & Pullen, 2011). It is an effective behavioral intervention to actively engage students (Blick & Test, 1987), enhance their academic skills (Maag, Rutherford, & Digangi, 1992), improve their productivity and accuracy (Rock, 2005), and positively impact student−teacher relationship (Reid, 1996). Successful self-monitoring requires students to self-regulate their academic progress and meet stated academic goals or complete required tasks (Porter & Ronit, 2006), where self-regulation is defined as "self-generated thoughts, feelings, and behaviors that are planned and cyclically adapted based on performance feedback to attain self-set goals" (Zimmerman, 1990).

The mechanisms through which students' cognitively manage their academic learning and engagement level are primarily influenced by four sets of psychological variables such as competence, autonomy and control, values and goals, and relatedness (Bandura, 1997; Dweck, 2000; Pintrich, 2003; Ryan & Deci, 2000).

1.1.1 Competence refers to the individual's ability to complete a specific task (Elliot & Dweck, 2005; Harter, 1978) such as students' belief about their academic competence and how it relates to their engagement, learning, and academic performance (Bandura, 1997; Dweck, 2000; Harter, 1982; Skinner, 1996; Skinner, Zimmer & Connell, 1998). Competence is determined by previous performance, vicarious learning, verbal encouragement, and physiological reactions (Bandura, 1977, 1997). Competence is addressed in the self-efficacy theory (Bandura, 1977, 1997); self-concept and self-worth theories (Covington, 1992; Harter, 1982), where the vision of one's self of the future can motivate behavior (Garcia & Pintrich, 1994; Markus & Wurf, 1987).

1.1.2 Autonomy and control refers to the motivation and willingness of individuals to engage in a specific task when feeling in control and are able to link required actions to desired outcomes. Pioneered by Deci and Ryan, the Self-Determination Theory (SDT) argues that students with greater sense of autonomy show high levels of academic engagement, persistence, and achievement (Deci & Ryan, 2002; Grolnick & Ryan, 1987), and their reasons for engaging are fully internalized (Ryan & Deci, 2000). To that extent, a study of differently structured reward programs by Fryer (2011) determined that rewarding students to increase their test score did not produce better results, in part because students had no control over their test scores, while on the other hand rewarding students for performing specific tasks such as reading books and taking a corresponding quiz, which students knew how to control, produced excellent results that persisted well past the duration of the study. Furthermore, Connell and Wellborn (1991) linked control beliefs to competence needs by concluding that individuals who believe they control their achievement outcome should feel more competent.

1.1.3 Values and goals refer to students' motivations to perform some academic tasks that are influenced by their perceived value, and students' goals for performing these tasks. Eccles and Wigfield (1995) defined four motivational components of task value: attainment value, intrinsic value, utility value, and cost. Wigfield, Eccles, Schiefele, Roeser, and Davis-Kean (2007) defined attainment value as the importance of doing well in a task, while intrinsic value is the enjoyment achieved from performing a task. Extrinsic value is the desire to achieve because of a certain objective and not so much for the enjoyment of the activity, while utility value is defined by how well a task relates to current and future goals, and reasons for engaging in terms of the lost opportunities resulting from making one choice rather than another.

Achievement goals theorists have identified two different types of achievement goals: mastery goals, and performance achievement goals (Ames, 1992; Dweck, 1986). Bandura and Schunk (1981), Bandura (1997), and Schunk (1991) argued that specific proximal goals combined with somewhat challenging goals promoted both self-efficacy and improved performance.

Furthermore, it has been argued that Future Time Perspective (FTP) is essential for students' engagement in learning, and function as roadmaps for their strategic learning (Hilpert et al., 2012). Therefore, if students believe that current educational activities are useful in the long run, they are more likely to be positively motivated, self-regulated, and achieve higher grades (Husman & Lens, 1999; Kauffman & Husman, 2004; Lens, 1986). Furthermore, research about the motivational relevance of a task's instrumentality and its utility value, supports the positive influence of future goals in an academic context (De Volder & Lens, 1982; Eccles & Wigfield, 1995; Miller, DeBacker, & Greene, 1999; Rheinberg, Vollmeyer, & Rollett, 2000; Simons, Dewitte, & Lens, 2000, Simons, Dewitte & Lens, 2004; Wigfield & Eccles, 1992).

1.1.4 Relatedness refers to the desire to feel connected to others (Ryan, 1992), and has been linked to important academic outcomes including self-efficacy, engagement, academic achievement (Furrer & Skinner et al., 2003), and motivation (Appleton et al., 2008). Students' perceptions of relatedness to their teachers have shown to positively impact their behavioral engagement and academic outcomes (Connell & Wellborn, 1991; Furrer & Skinner et al., 2003; Goldstein, 1999; Ryan, Stiller, & Lynch, 1994; Ryan & Powelson, 1991). Research also indicates that student motivation can be influenced through classroom reward structure (Ames & Ames, 1984), classroom organization (Rosenholtz & Wilson, 1980), and curriculum (Renniger, Hidi, & Krapp, 1992).

Although the application of the Ordinary Least Square (OLS) in assessing and/or predicting students' performance in many business disciplines has been well-documented in the literature, such as accounting (Buckless, Lipe, & Ravenscroft, 1991; Danko, Duke, & Franz, 1992; Eikner & Montondon, 2006; Gracia & Jenkins, 2003; Hartnett, Römcke, & Yap, 2004; Kealey, Holland, & Watson, 2005; Koh & Koh, 1999; Naser & Peel, 1998; Turner, Holmes, & Wiggins, 1997), marketing (Borde, 1998), management science (D'Souza & Maheshwari, 2011), and operations management (Peters, Kethley, & Bullington, 2002), the logistic regression has been shown to be superior (to OLS) at predicting the probability of an attribute (Pohlmann & Leitner, 2003), such as students likelihood of success (Goldstein & Perin, 2008; Zhang, Patel, & Ewing, 2014), or in determining the drivers of students' performance (Estelami, 2014; Tseng, 2010).

It is worth noting that the literature review did neither reveal any research that actively involve the student in the prediction process, nor any combined use of the suggested predictive tools to assist students in both gaging the gap between their current academic performance and their future desired outcomes, and in quantifying their likelihood of success. Hence, this study aims at bridging this existing gap in the literature by drawing from the motivation achievement theories of educational psychology and the use of predictive analytics to provide the necessary tools to engage students in self-monitoring and self-regulating their own performance for the purpose of better outcome and continuous improvement.

1.2. Background

With many students showing apprehension, fear, and concern from the first day of class, this junior level quantitative business course requires statistics as a prerequisite, and is considered by many as one of the most demanding and difficult course in the business curricula. Although the students' first exam's historical average is quite acceptable (72.54% over the first four year period of the study), the grade distribution over the same period clearly substantiate the students' anxiety toward this course with about 38% scoring either D or F on their first exam as shown in Fig. 1. Inputs from students revealed that math anxiety and lack of perceptions of the utility of the course work were the main culprits.

Changes to the course design, management, and delivery and the adoption of a newer textbook did not result in any significant improvement in the students' performance or attitude toward the course over the initial 4 years of the study (pre-innovation group). Furthermore, the growing concern about the poor performance in the aforementioned quantitative business course prompted the need for a change to create a better course environment and an improved student engagement, hence the idea of combining the motivation achievement theories and predictive analytics to enhance the students' academic performance, and provide them with effective tools to assist them in linking their current actions to their future goal of passing the class.
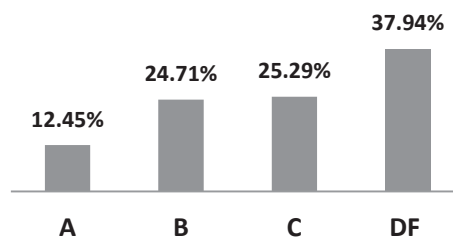

Fig. 1. First exam (E1) – grade distributions.

1.3. Proposed improvements

Applying the FTP theory (Husman & Lens, 1999; Kauffman & Husman, 2004; Lens, 1986) to relate current educational activities to future goals, e.g. passing the course, students were required to use a database of multiple graded activities of assignments, quizzes, exam scores, final scores, apply the (OLS) regression skills learned in this analytical course to develop a multiple regression model to predict their likely final grade. Furthermore, to alleviate self-doubts and assist the students in quantifying their likelihood of success in the aforementioned course, students were provided a logistic regression model where the probability of an event is determined using the regression or logit coefficients denoted as "b" as shown in the model below

$$P(event) = \pi j = 1 \Big/ \left(1 + e^{-(b0+b1X1+...bkXk)}\right)$$

As described by Rahal and Rabelo (2006), "The binary logistic regression uses the iterative Maximum Likelihood Estimation (MLE) fitting procedure for predicting a probabilistic classification outcome by finding those coefficients that have the greatest likelihood of producing the pattern of the observed data. A trial estimate of the coefficients are initially proposed, tested, and then re-estimated until a convergence has been reached. The optimal solution is reached by maximizing the Log-Likelihood (LL) or minimizing the −2 Log-Likelihood (−2 LL) function which indicates how probable, how likely, or the odds on how to obtain the observed values of the dependent variable (outcome 0 or 1), given the observed values of the independent variables". Using the existing dataset, both predictive tools (the linear and the logistic regression) were modeled and tested with an accuracy rate exceeding 86% as early as the first exam as shown in Table 1 below.

A spreadsheet containing both predictive tools was then made available to students to be updated for continuous feedback throughout the duration of the course as shown in Fig. 2.

If and when unsatisfied with their class performances or the real time feedback of the predictive tools (predicted grade or likelihood of passing the course), students of the post innovation group were directed to either self-regulate their class engagement, and/or seek the intervention of their instructor to provide remedies to facilitate their success.

Achievement goals theorists argued that proximal goals combined with somewhat challenging goals promoted both self-efficacy and improved academic performance (Bandura, 1997; Bandura & Schunk, 1981; Schunk, 1991). As such, long and tedious assignments were divided into smaller ones with added complexity and multiple allowed attempts (non-multiple choice questions). Given the online assessments' immediate performance feedback capability and its positive association with perceived competence (Raska, 2014), students had the opportunity to react and self-regulate their class engagement and mastery skills, and and promote their self-efficacy and competence.

Stemming from self-determination theorists who argue that students with a greater sense of autonomy show high levels of academic engagement, persistence, and achievement (Deci & Ryan, 2002; Grolnick & Ryan, 1987), students were allowed the flexibility to submit quizzes and assignments (both performed online) on time for a full score or late for a preset penalty; hence, a lower perceived value. It is worth noticing that unlike the students who have taken the course over the initial four years of the 5-year longitudinal study (group 1, pre-innovation), students in the fifth year (group 2, post-innovation) worked diligently to submit their work prior to the due dates to avoid any penalty. On time assignments completion increased substantially.

Following other researchers lead which argues that students' perceptions of relatedness to their instructor have shown to positively impact their behavioral engagement and academic outcomes (Connell & Wellborn, 1991; Furrer & Skinner et al., 2003; Goldstein, 1999; Ryan et al., 1994; Ryan & Powelson, 1991), the instructor instituted an open door policy in which students could at will discuss their assignments or any of their concerns about the class.

2. Analysis and results

Motivated by all of these new changes, the research question in this study was to determine if the newly implemented innovation had any impact on students' performance.

2.1. Pre-innovation analysis

We initially posit that no difference exists between the two groups up to and including the first exam and prior to the implementation of the pedagogical innovation and students' use of predictive analytics. Hence,

Table 1
Predictive tools and accuracy rates.

Variables	Linear regression (OLS) pass/fail accuracy rate	Logistic regression pass/fail accuracy rate
After first exam (HW, Q, E1)	86.1%	88.9%
After the second exam (HW, Q, E1, E2)	87.9%	90.0%
After the third exam (HW, Q, E1, E2, E3)	88.5%	92.4%

Enter your Quiz Average	68.00		
Enter your Homework Average	71.00		
Enter your Exam#1 Score (when available)	70.00		
Enter your Exam#2 Score (when available)			
Enter your Exam#3 Score (when available)			
Given your current class performance, your predicted score and likelihood of passing are	**Your Predicted Course Average**	**Your Likelihood of Passing this Course**	**Your Current Course Average**
Your predicted score (Q, HW, E1)	67.50	72.06%	69.80
Your predicted score (Q, HW, E1, E2)			
Your predicted score (Q, HW, E1, E2, E3)			

Fig. 2. Predictive tools spreadsheet.

$$H0 : \mu G1E1 - \mu G2E1 = 0 \quad \text{no difference between the 2 groups}$$

$$H1 : \mu G1E1 - \mu G2E1 \neq 0 \quad \text{there is a difference between the 2 groups}$$

where

- where $\mu G1E1$ represents the mean score of the pre-innovation group (group 1) up to and including the scores of the first exam (E1), where group 1 consisted of 511 representing all student enrollees in years 1—4, and
- $\mu G2E1$ represents the mean score of the post-innovation group (group 2) up to and including the scores of the first exam (E1), where group 2 consisted of 147 representing all student enrollees in year 5.

Analysis shows the means and the variances of the two groups were comparable as shown in Table 2.

Conditions of a two-sample t-test of independent samples of normal populations and equal population variances (difference between the variances was statistically insignificant with Levene's test of p-value of .36) were met as shown in Table 3, with no significant difference between the performance of the two groups up to and including the first exam (E1) at the 5% significant level (P-value of .0998).

This result was expected given the suggested innovation and the fact that predictive analytics tools would not be implemented until after the first exam's results were known, hence students were not yet able to assess and/or self-monitor their own progress, nor apply the predictive tools to make that connection between their current performance and their goal of passing the course.

2.2. Post-innovation analysis

Comparing the overall final performance score results of the two groups of students, we posit that the pedagogical innovation and the use of predictive analytics enhanced group 2 (post-innovation) performance compared to that of the pre-innovation group (group 1). Hence,

$$H0 : \mu G1F - \mu G2F \geq 0$$
$$H1 : \mu G1F - \mu G2F < 0$$

where

- $\mu G1F$ represents the course overall final score for the pre-innovation group (group 1), and
- $\mu G2F$ represents the course overall final score for the post-innovation group (group 2)

The means and the variances of the two groups are shown above in Table 4. Furthermore, the required conditions of a two-sample t-test of independent samples, normal populations, and equal population variances (Levene's test of p-value of .610) were met as shown in Table 5.

The statistical analysis of the two groups overall scores shows a P-value of .007 (Sig. 2 tailed/2) and a t-statistic of −2.461 (t-critical one tail of −1.647), hence rejecting the null hypothesis in favor of the alternative and concluding that the use of the pedagogical innovation was effective in enhancing the students' performance.

Despite the increased complexity of the covered subject matter over the duration of the semester, further analysis of the post-innovation group (group 2) performance showed an improvement of about 4.7 percentage points in the students' average final score when compared to their performance average by the first exam (see Table 6), with a t-statistics value of

Table 2
Descriptive statistics- groups performance by Exam1.

	Groups	N	Mean	Std. deviation	Std. error mean
E1	Group 1	511	72.545	15.267	.6754
	Group 2	147	70.227	14.169	1.169

Table 3
t-Test: two-sample assuming equal variances.

	Levene's test for equality of variances		t-Test for equality of means					95% confidence interval of the difference	
	F	Sig.	T	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
E1	.839	.360	1.648	656	.0998	2.318	1.407	−.4439	5.0802

Table 4
Descriptive statistics-course overall final score.

Group	N	Mean overall final score	Std. deviation	Std. error mean
G1F	511	72.153	12.2657	.5426
G2F	147	74.923	11.1422	.91904

Table 5
t-Test: Course Overall Group Performance.

	Levene's test for equality of variances		t-Test for equality of means					95% confidence interval of the difference	
	F	Sig.	T	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
Overall score	.261	.610	−2.461	656	.014	−2.7699	1.1254	−.4.9795	−.5597

−6.685 and P-value of "0" (see Table 7) confirming the effectiveness of the use of motivation achievement theories of educational psychology and predictive analytics.

Comparing the grade distribution of the two groups (Fig. 3), it can be easily seen that the post-innovation group of students outperformed those in the pre-innovation group with 43% more As (from 6.58% to 9.40%), 35% more Bs (from 19.34% to 26.17%), and 20% fewer Cs (from 50.48% to 40.27%). Although the failure rate of the at-risk students (DFWs) stayed at about 24%, the majority of these students eventually succeeded in passing the course, thanks to their improved class engagement, and the instructor's proposed remedies to facilitate their success. Hence, further confirming the effectiveness of the use of motivation achievement theories of educational psychology and predictive analytics.

Comparing the post-innovation group grade distributions, Fig. 4 clearly shows a significantly improved performance by the end of the course compared to that by the first exam with 27% more As, 22% more Bs, 62% more Cs, with almost 48% of at-risk students (DFWs) being remedied.

To further validate the efficacy and sustainability of the proposed innovation, data for 79 students in the first semester of year six (group 3) and a one way Analysis of Variance (ANOVA) was performed for all the three groups concluding that the data provides substantial evidence of at least one significant difference in the final score performance of the three groups. Tuckey's Honestly Significant Difference Test (HSD) confirmed a significant difference between group 1 and groups 2 and 3 with no significant difference existing between groups 2 and 3 (see Tables 8 and 9).

Table 6
Descriptive statistics post-innovation group. Exam1 & course final average.

		Mean	N	Std. deviation	Std. error mean
Post-innovation group 2	G2E1	70.22721	147	14.169495	1.168680
	G2F	74.92271	147	11.142209	.918994

Table 7
Paired t-test post-innovation group exam1 & course final average.

		Paired differences					T	df	Sig. (2-tailed)
		Mean	Std. deviation	Std. error mean	95% C. I. of the difference				
					Lower	Upper			
Post-innovation group 2	G2E1–G2F	−4.6955	8.5165	.7024	−6.0838	−3.3073	−6.685	146	.000
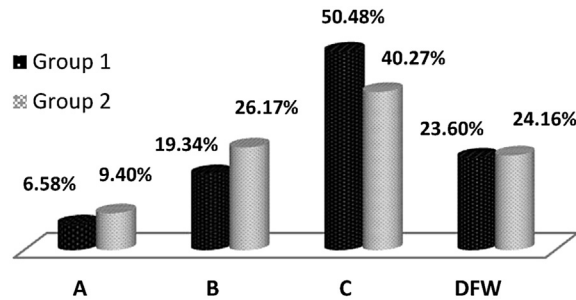
Fig. 3. Pre-innovation group (1) vs. post-innovation group (2) final grade distributions.
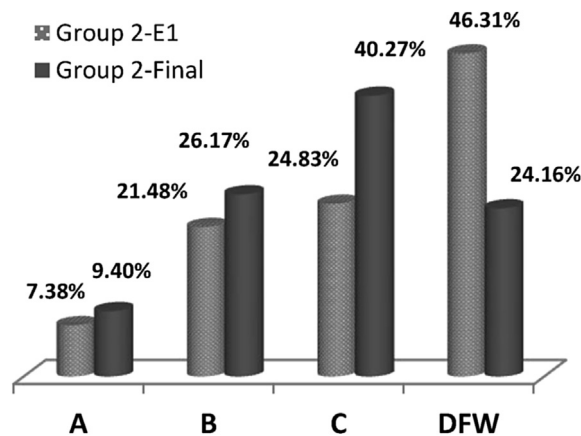
Fig. 4. Post-innovation group (2) grade distributions as of exam1 vs.-final grades.

Table 8
ANOVA-Final course performance score-all groups.

	Sum of squares	df	Mean square	F	Sig.
Between groups	2915.950	2	1457.975	10.017	.000
Within groups	106835.983	734	145.553		
Total	109751.933	736			

Table 9
Multiple comparisons- Tukey's HSD- dependent variable: Final course average.

(I) group	(J) group	Mean difference (I-J)	Std. error	Sig.	95% confidence interval	
					Lower bound	Upper bound
Pre-innovation (group 1)	2	−2.769584[a]	1.129158	.038	−5.42138	−.11779
	3	−5.997122[a]	1.458521	.000	−9.42242	−2.57182
Post-innovation (group 2)	1	2.769584[a]	1.129158	.038	.11779	5.42138
	3	−3.227538	1.683033	.134	−7.18010	.72502
Group 3	1	5.997122[a]	1.458521	.000	2.57182	9.42242
	2	3.227538	1.683033	.134	−.72502	7.18010

[a] The mean difference is significant at the .05 level.

3. Results and conclusion

This study provides statistical evidence to support the hypothesis that combining motivation achievement theories of educational psychology and predictive analytics can positively influence the academic performance of students in quantitative business courses. Unlike existing research, this study required students to play an active role in the development of the predictive tools and the prediction process, and provided them the capability to capture real-time performance feedback enabling them to relate their current educational activities to future goals, hence providing them the opportunity to react and self-regulate their class engagement. This positive learning environment promoted self-efficacy and competence, improved students' self-confidence, and led to higher levels of class engagement, relatedness, and improved mastery skills, as illustrated in Fig. 3, making the course more enjoyable to both students and instructors.

Given the vast and challenging endeavor of student academic performance, this study also sought to show an approach that transcends classical learning goals to include experiential learning, and provide a process that educators and practitioners may find useful to facilitate a student-based active learning environment. Furthermore, the authors believe that this study can be replicated across many courses and disciplines, and may provide a continuous improvement tool to enhance students' academic engagement, and provide them the opportunity to see the likely outcome of their current class performance. It should be noted that this study is limited to the motivation achievement theories the authors deemed appropriate for their specific use and does not in any way claim to be applicable under all circumstances.

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