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Motivation Strategies and Exiting Class by Students in Inquiry-Oriented Biology Labs

ABSTRACT

Experimental inquiry-oriented science labs can be designed to have students regulate their own learning and decide when they leave class or to have the teacher regulate student learning and determine when they leave class. In this study, grades were examined relative to student exit times in a student-regulated class design. Preliminary interviews revealed four motivation strategies likely to differentially influence exit times and grades: proficiency, grade-target-A, grade-target-C, and time-limited. Students were categorized into the four groups of motivation strategies with a survey. Twenty teaching assistants teaching three lab sections each taught the stand-alone lab class. Students recorded the time they left class each week. Grades were determined as the overall percentage of points a student received in class. Results of the survey showed that the four motivation strategies were well represented in the student population, and two additional strategies were also frequently seen: a hybrid-1 between proficiency and grade-target-A, and a hybrid-2 between time-limited and grade-target-C. Grades were significantly higher for grade-target-A and hybrid-1 students, followed by time-limited, proficiency, grade-target-C, and hybrid 2. Time spent in class was not significantly different among categories. Students who chose to stay in class longer had significantly higher grades. If a grade is the goal, these results support the idea of a teacher-controlled exit time for the students in these inquiry-oriented labs. Implications are discussed.

KEYWORDS

inquiry, biology-lab, self-regulation, grade-target, time-allocation

INTRODUCTION

When designing an inquiry-oriented lab curriculum, teachers are faced with the decision of allowing students to choose to leave class early (self-regulation) or insisting that students finish up with all they can during class time (teacher regulation). For example, one potential design for an experimental lab is to have students plan their experiment and use equipment to gather data, but once the data have been consolidated, allow students the option of self-regulation by leaving class and completing the write-up and data analysis on their own. There would seem to be a clear advantage for learning in a teacher-regulated design: while in class, students have help from their instructor, and they have the benefit of peer and group discussions. On the other hand, students have many demands upon their time, and they may prefer to use their time at any particular moment for a different and legitimate purpose, such as studying for an exam, meeting with peers to plan an important event, eating (because they have no time

later in the day). If a student decides to leave lab early, the student is expected to self-regulate and make up the lost time outside of class; the student could earn the same grade as did a student who elected to stay in class.

Self-regulated time allocation by students relative to grades has been a topic of great concern. Numerous studies have examined the relation between class attendance and grades, and they have predominately shown a strong and positive association between class attendance and grades (Arulampalam, Naylor, and Smith 2012; Dobkin, Gil, and Marion 2010; Kwak, Sherwood, and Tang 2018; Lukkarinen, Koivukangas, and Seppälä 2016; Stanca 2006). From a two-year study on a cohort of undergraduate students, Valentin Kassarnig, Enys Mones, Andreas Bjerre-Nielsen, Piotr Sapiezynski, David Lassen, and Sune Lehmann (2018) used data collected from smartphones on social networks to evaluate various factors associated with academic performance and found the leading factor to be lecture attendance. Barbara Grave (2011) used a common survey on time allocation and related the results of the survey to grades over 24 years at a German university. Results indicated grades were highly correlated with attendance, time spent on self-study, time spent on other study-related activities, and time spent working as a student assistant or a tutor. Recent research has indicated that teachers can make a difference in student time commitment. Liugen Zhu, Edgar Huang, Joseph Defazio, and Sara A. Hook (2019) demonstrated class attendance was significantly influenced by the stringency of a teacher's attendance policy. Although research on time allocation and grades is common, the research does not adequately address which is the better design for finishing up inquiry-oriented labs, self-regulated or teacher regulated. No research we are aware of has addressed the relationship between time stayed in lab by students at the end of inquiry-oriented labs and grades. The primary goal of this study was to examine this relationship.

General biology labs at the University of Colorado at Boulder use a design that allows students the freedom to stay or leave near the end of lab. Sixty sections of the class meet weekly and run in four rooms simultaneously. Prior to this study, preliminary observations of the classes indicated two distinct patterns:

1. There was variation in how long students stayed in class.
2. There was variation in study behaviors.

Prior to this study, from informal preliminary interviews, students indicated they viewed their study time as limited and would commonly use different strategies for study-time allocation. The three most common motivations indicated by students were grade targets, time-limitation, and proficiency. When motivated by grade targets, students commonly reported striving to reach a grade target of either a C grade to pass the class or an A grade to maximize their grade point average, and once they had invested enough time to reach the target they said they would leave class. When motivated by time-limitations, students commonly reported that as the lab was a one-credit lab, they would set a given amount of time to invest that was less than that for a five-credit class. Those students seeking proficiency commonly reported that learning discipline-specific content was their primary goal and achieving a specific grade was not an important determinant for their study-time investment. They wanted to master the material to some intrinsically set level.

Study goals

The study addressed the primary question: ***How did time stayed in lab influence grades?*** Since student interviews indicated a proportion of students were likely to use motivation strategies, and the

motivation strategies were likely to influence student's investment of time both in and out of class and their overall grades, the study had four secondary questions:

1. What was the prevalence of the four motivation strategies within the lab class?
2. Were there differences in time stayed of students between the four motivation categories, and if so, what were the differences?
3. Were there differences in grades between the four motivation categories, and if so, what were the differences?
4. Was there a relationship between time stayed and grades? If so, were there differences in the relationships between time stayed and grades for the four motivation categories? And if so, what were the differences?

METHODS

Targeted class

The study was conducted at the University of Colorado at Boulder in fall 2014. The targeted class was General Biology Lab I, a stand-alone, one-credit-hour, freshman-level lab class that ran concurrently with a three-credit-hour lecture class addressing similar content. The class enrolled approximately 1,080 students, mostly freshman (60 percent) and sophomores (30 percent), with a few juniors (5 percent) and seniors (5 percent). The class was taught by 20 graduate-student teaching-assistants. Each teaching assistant taught three lab sections with up to 18 students in each section. Students enrolled in a section based upon time of day and were divided alphabetically into four different treatment groups each taught by a single teaching assistant. The assistants chose teaching times based on their own course schedules and through negotiation with other assistants (see table 1).

Table 1. Room assignments and section numbers for each graduate teaching assistant

Time	Monday	Tuesday	Wednesday	Thursday
8 a.m.–10 a.m.	1, 11, 12, 17	1, 3, 7, 13	5, 15, 19, 20	2, 3, 5, 7
10 a.m.–noon	10, 12, 14, 17	6, 7, 9, 16,	5, 15, 18, 20	2, 10, 16, 18
noon–2 p.m.	4, 12, 14, 19	6, 8, 9, 13	3, 15, 18, 20	2, 4, 8, 13
2 p.m.–4 p.m.	1, 11, 14, 19	6, 8, 9, 16		
4 p.m.–6 p.m.	4, 10, 11, 17			

Note: Seventy-two students signed up for a two-hour lab, which met one day a week. The 72 students were assigned to four different rooms randomly (alphabetically). Each graduate teaching assistant taught three classes and had to negotiate for teaching times in such a way that all teaching times were filled with four assistants. Teaching assistants were numbered alphabetically by last name. This table indicates that although teaching assignments were not completely random, they were fairly close to a random design.

A single class (section), met once per week for 1 hour and 50 minutes. The labs were designed as inquiry-oriented experiences. During the first one to one and a half hours, students worked on experiments in groups of two to four and ended by gathering data at their own pace. The remaining 20 to 50 minutes were self-regulated: students completed the data analysis in their respective groups and briefly wrote up their experiments as individuals while continuing to interact with their group members, other students in the room, or the teaching assistant.

On the first day of class, the study was explained to the students, and students were allowed to participate by signing an informed consent document. Participating students received two extra-credit points toward their grade in the class. An equivalent extra-credit opportunity was given to students who did not elect to participate. All research was conducted following the protocol accepted by the university's institutional review board.

Motivation strategy survey

The purpose of the motivation strategy survey was to place students into the four categories: proficiency, grade-target-A, grade-target-C, and time-limited. The survey consisted of two sets of four statements. Each statement was associated with a single motivation strategy. Students were asked to rank the statements as 1, 2, 3, or 4, with 4 as the most representative statement and 1 as the least representative statement. Content validity was verified by a group of eleven students who were interviewed after they took the initial version of the survey. Following the interviews, the survey was modified accordingly. Survey reliability was determined by comparing student consistency in answering each of the two sets of four questions with a Pearson's Correlation Coefficient. For the students included in the study (N =739), the results indicated that the survey was adequately reliable (proficiency, r = 0.69; time-target-A, r = 0.68; time-target-C, r = 0.65; time-limited, r = 0.73).

The two sets of statements used in the final survey follow.

- I had many demands on my time this semester, so my goal was to simply invest enough time in this class at least to pass and use any extra time for other activities (i.e., other classes, social, leisure, play, and/or work).
- I did not care this semester if I had limited time or not. My goal this semester was to invest enough time in this class to get an "A" grade.
- I invested time in this class because I prized learning and mastering the material above all else, including getting an "A" grade.
- I had limited time this semester. Since this was a one-credit biology lab, I set aside a specific amount of time to work on this class, and I was willing to accept whatever grade I received in the end.
- My goal was to invest enough effort in this class to learn the subject. I was not striving to get a specific grade. I would have sacrificed an "A" grade for a lower grade as long as I mastered the material.
- My goal was to invest enough effort in this class to get an "A" grade even if the extra effort had a negative impact on my other activities (i.e., other classes, social, leisure, play, and/or work).
- I invested enough effort in this class to get a passing grade, and the time I saved I used on my other activities and classes.
- I had limited time this semester. Since this was a one-credit biology lab, I set aside a specific amount of time to work on this class, and I was willing to accept whatever grade I received in the end.

The survey was set up in Qualtrics®. Students were given one opportunity at the end of the semester to take the survey. Although the surveys were anonymous, students were given a unique identification number so their scores on the survey could be associated with other items of data.

Grades and time stayed

Two associated items of data were gathered: the time students stayed in class and their final grade. Each week, participating students were asked to record the time they left class. Grades were determined by teaching assistant-derived quizzes, written reports graded by the teaching assistants, and a common final exam. A single percentage grade was recorded for each student. Quizzes represented 29 percent of the total grade and used a mixed style, with questions ranging from Bloom's lower cognitive levels (multiple choice, fill in the blank, matching, short answer) to Bloom's higher order cognitive levels (short to medium-length answers addressing application, synthesis, or analysis levels). Written reports worth 49 percent of the final grade mainly consisted of individually written statements of the hypothesis studied, predicted results, a results section of data tables and student-derived figures, a short discussion on how the results relate to the hypothesis, and an evaluation of the study validity and reliability.

The final exam, worth 22 percent of the final grade, was designed to examine inquiry skills. For the exam, students were given two scenarios. For the first scenario, students were given an observation associated with one of the inquiry-oriented labs and asked to derive a hypothesis, derive methods to test the hypothesis utilizing equipment introduced during the semester, derive a prediction, and discuss the use of controls. For the second scenario, students were given a hypothesis, brief methods, and a data table. Students were asked to statistically analyze the results using R, graph the results, and draw conclusions.

RESULTS

The motivation survey placed 68 percent of the students into the four expected categories: proficiency = 191; grade-target-A = 182; time-limited = 141; and grade-target-C = 134.

Two additional categories appeared from the assessment, and when added represented a total of 79 percent of the students. The first category, called hybrid 1, consisted of students who ranked proficiency first and grade-target-A second on one set of questions and grade-target-A first and proficiency second on the other set of questions ($n = 67$). Generally speaking, these students sought to master proficiency but would not sacrifice an A grade in the pursuit of proficiency. The second category, called hybrid 2, consisted of students who ranked time-limited first and grade-target-C second on one set of questions, and grade-target-C first and time-limited second on the other set of questions ($n = 46$). Only a small number of students interchanged first and second rankings between sets of questions for grade-target-A and grade-target-C ($n = 12$); proficiency and grade-target-C ($n = 9$); grade-target-A and time-limited ($n = 5$); and proficiency and time-limited ($n = 4$).

Finally, a subset of students inconsistently ranked the categories of motivation between the two sets of questions ($n = 167$).

Descriptive statistics associated with time stayed in class are listed in table 2 and descriptive statistics associated with grades are listed in table 3.

Table 2. Descriptive statistics associated with time stayed

Time Stayed	Maximum	Minimum	Range	Mean	SD
Individual	116.9 min	72.4 min	44.5 min	98.8 min	8.1 min
Class	109.2 min	81.0 min	28.2 min	98.8 min	7.0 min
Relative	28.7 min	15.3 min	-13.4 min	0.0 min	4.0 min
Normalized	1.46	0.71	-0.75	0.00	0.19

Note: Individual = individual time stayed and is the number of minutes the student stayed in class averaged for all labs across the entire semester (N = 739 students). Class = the mean time students in a single class (section) stayed averaged for all lab meetings across the entire semester. For example, students in the 8–10 a.m. class on Monday with a specific teaching assistant may have left consistently earlier all semester than did those in the 2–4 p.m. class on Wednesday with a different teaching assistant (n = 60 classes). Relative = individual time stayed relative to class and was calculated by the following equation: mean class time stayed – individual time stayed. Normalized = the normalized time stayed and was calculated by the following equation: (mean class time stayed – individual time stayed) / mean class time stayed. SD = standard deviation.

Table 3. Descriptive statistics associated with student grades

Category	Minimum (%)	Maximum (%)	Range (%)	Mean (%)	SD (%)
Individual	22.4	100.0	79.4	83.6	8.8
Class	73.3	89.8	16.5	83.6	8.8
Relative	-56.3	21.0	77.3	0.0	8.1

Note: Individual = individual grade reported as the percentage a student received in the class. Class = mean class grade. Relative = individual grade relative to class and was calculated by the following equation: individual grade – mean class grade. SD = standard deviation.

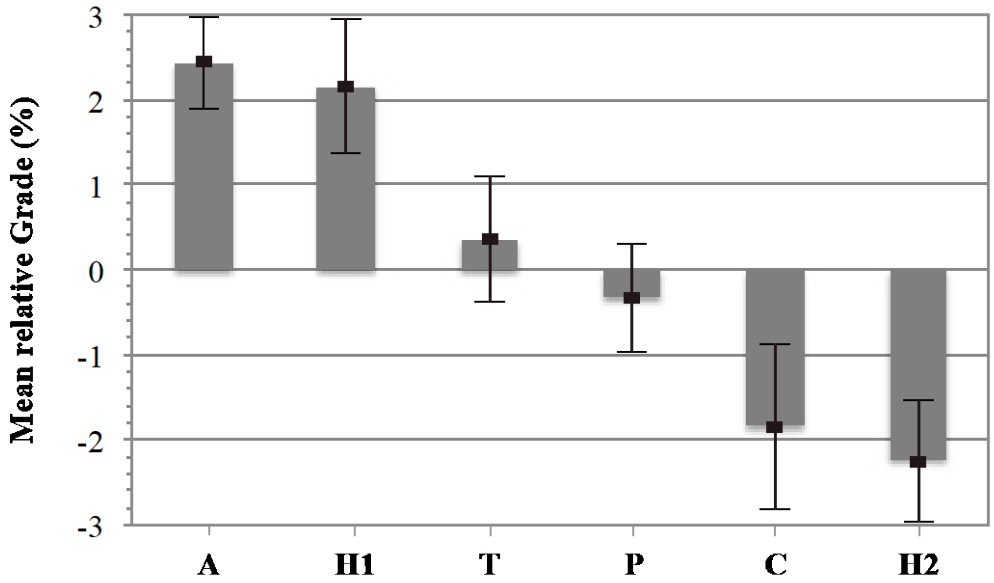
Mean raw grades varied between motivation groups (A = 86.3 percent, H1 = 86.1 percent, T = 84.0 percent, P = 82.6 percent, C = 82.2 percent, and H2 = 82.1 percent). We ran an ANOVA to examine whether relative grades and relative time stayed were different between motivation categories. There was a significant difference between motivation categories for relative grades ($P < 0.0001$), but there was no significant difference between motivation categories for relative time stayed ($P > 0.05$, table 4). We used a Tukey's range test to examine differences between individual motivation categories and relative grades. The grades of grade-target-A students were not significantly different from those of the students in the hybrid 1 or time-limited categories ($P > 0.05$), but it was significantly greater than those of the students in the proficiency ($P = 0.02$), grade-target-C ($P = 0.0001$), and hybrid 2 ($P = 0.001$) categories. The grades of hybrid 1 students were significantly greater than those of the grade-target-C students ($P = 0.02$, figure 1).

Table 4. Mean relative grade (%) and relative time in class (minutes) ± one standard error for each motivation category

	A	H1	T	P	C	H2
Grade	2.42±0.57	2.16±0.91	0.34±0.73	-0.33±0.64	-1.84±0.95	-2.23±0.86***
Time	0.44±0.33	-0.53±0.49	-0.05±0.33	-0.03±0.28	0.60±0.34	-0.24±0.62

*** $P < 0.001$.

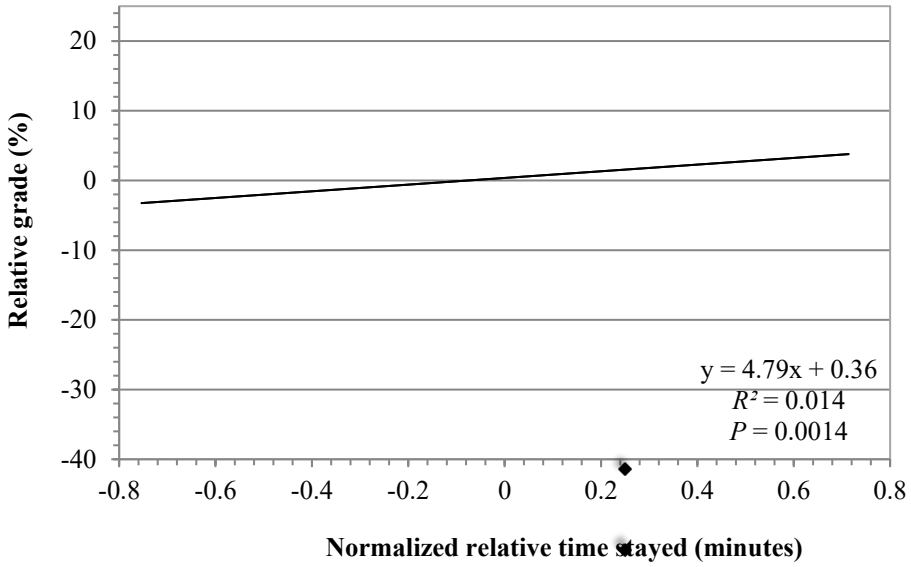
Figure 1. Mean relative grades (± one standard error) for students with different motivation orientations



The results for grade-target-A students were not significantly different from those of hybrid-1 students or time-limited students ($P > 0.05$), but they were significantly different from those of the students in all other motivation categories ($P < 0.05$). Results for hybrid-1 students were significantly different from those of grade-target-C and hybrid-2 students ($P < 0.05$). The results in all other categories were not significantly different from one another ($P > 0.05$).

A linear regression was used to analyze relationships between time stayed and grade in general. The linear regression analysis revealed a significant positive effect of time stayed on grade (figure 2). A linear mixed-effect model was used to examine the effect of normalized time stayed on arcsine-transformed grades within individual motivation categories, between motivation categories, and for verification of the linear regression analysis by including all motivation categories. An information-theoretic approach (Burnham and Anderson 2002, 352–436) was used with Akaike's information criterion corrected for small sample sizes (AIC_c). Teaching assistant and section were treated as random effects in all models to account for the hierarchical study design and to control for heterogeneity independent of student motivation categories. We also included motivation as a random effect in a global model that included all motivation categories based on the observed differences in grades in each category. We concluded that normalized time stayed had a strong influence on grade if the 95 percent confidence interval did not overlap zero. The results showed the only individual motivation category that showed a significant effect of time stayed on grade was students motivated by time-limitations. All other motivation categories did not show a significant effect (table 5). When the two groups of grade-target students were combined, no significant effect on time stayed on grade was seen (table 5). When grade-target-A, proficiency, and hybrid 1 were combined, there was a significant effect of time stayed on grade (table 5). Finally, the global model with the motivation category as a random effect also showed a significant effect of time stayed on grade (table 5).

Figure 2. The relative grade a student received in the class (table 3) versus the normalized relative time stayed (table 2).



There was a significant positive relationship between the variables $P < 0.005$, thus indicating students who stayed in class longer overall were more likely to receive higher grades.

Table 5. Results of the linear mixed effect model examining the effect of normalized time stayed on arcsine-transformed grade.

Motivation category	Effect	2.5%	97.5%	*n*
P	0.05	-0.06	0.15	186
H1	0.11	-0.11	0.33	64
A	0.11	-0.004	0.23	177
C	0.05	-0.10	0.20	130
H2	0.05	-0.13	0.22	46
T	**0.18**	**0.02**	**0.35**	**136**
A + C	0.09	-0.002	0.18	307
A + P + H1	**0.09**	**0.02**	**0.15**	**557**
Global model	**0.10**	**0.04**	**0.16**	**739**

Note: 2.5 percent and 97.5 percent reflect the 95 percent confidence interval (CI) and *n* reflects sample size for each model. Boldface rows indicate strong effects (i.e., 95 percent CIs do not overlap zero) within the category.

Strong positive effects were present between time stayed and grades for three models, T, A + P + H1, and the global model included all motivation categories.

DISCUSSION

The overall goal of this study was to shed light on the question of whether to allow students to self-regulate class time when designing inquiry-oriented experimental labs. Two routes of addressing this question were to (1) do a correlational analysis of time stayed relative to grade or (2) use a two-treatment, quasi-experimental design.

The problem with the two-treatment design was the potential influence of the confounding variable of student motivation strategies. The potential for a synergistic effect in individual classes

caused by varying percentages of students with different motivation strategies could give individual classes their own exiting "personalities," so to speak. This would decrease the overall sample to individual classes and be further confounded by the teaching assistant. Thus, a correlational analysis based on the individual categories of motivation strategies and adjusting for differences between teaching assistants in the analysis is a legitimate alternative and is what was used in this study.

The preliminary informal surveys indicated student motivation strategies were important variables to consider. The results of this study supported the findings of the preliminary surveys and indicated a substantial percentage of students consistently classified themselves into one of the four primary motivation strategies (proficiency = 19.9 percent, grade-target-A = 19.0 percent, grade-target-C = 14.7 percent and time-limited = 14.0 percent). When the two hybrid categories were included, 79.4 percent of the students were classified successfully into motivation strategies, while only 20.6 percent of the students could not be classified into any of the categories. Since achievement motivation is complex (see Murphy et al. 2019) the number of students successfully placed by the survey was higher than we expected. No prior research we are aware of has ever categorized students based on these motivation strategies, and the high percentages of students categorized consistently indicates these strategies have promise for further study. Note that while the teacher dictates the time investment needed for grade targets and students receive constant feedback in attaining those targets, both time-limited and proficiency strategies are determined by the students themselves. Thus, more research is needed to more fully elucidate the factors affecting time allocation for students using time-limited and proficiency strategies.

Although grades were significantly different between the motivation strategies of the students (table 4, figure 2), the relative time stayed was not (table 4). This finding is not necessarily consistent or inconsistent with either design of inquiry-oriented labs because this finding could result from several factors. First, students with different motivation strategies on average may have allocated different amounts of time to study outside class to make up for the differences in grades. Massimiliano Bratti and Stefano Staffolani (2013) demonstrated that the positive effects of lecture attendance on academic performance can be counteracted by self-study outside of lecture. Second, students using different motivation strategies may have had different learning curves relative to time. For example, grade-target-A students may have had more associated classes in the past than did grade-target-C students, thus, allowing them to learn the material faster. Third, both of the first two factors may have occurred simultaneously. The influences of such variables were not examined in this study.

The primary support for a teacher-regulated design over a self-regulated design is through the positive relationship between time stayed in class and grades (figure 2). Additionally, the linear mixed-effects model analysis showed the global model, the model combining the three grade-targeted strategies (A, C, and H1), and the model using the single category of time-limited students all showed a significant positive effect of time stayed on grade (table 5). However, the other models did not show a significant relationship. The significant positive relationships in general support the contention, while the nonsignificant relationships open the door for the possibility of variation due to group trends in study time allocation for students with different motivation strategies. The need for more research in this area is apparent.

Educational implications

Prior research has predominantly indicated that attendance in a live classroom setting not only is positively correlated to student success in the form of grades (Arulampalam, Naylor, and Smith 2012; Dobkin, Gil, and Marion 2010; Kwak, Sherwood, and Tang 2018; Lukkarinen, Koivukangas, and Seppälä 2016; Stanca 2006), but it also has shown attendance is a, if not the, primary contributor to student success (Grave 2011, Kassarnig et al. 2018). This study supports these findings and adds one more piece to the puzzle, demonstrating that in inquiry-oriented labs where students have the opportunity to leave class early or stick around, students who choose to leave early do so at a cost to their grades. Thus, the importance of in-class study and the ability to interact with peers and a teacher may be an important factor to consider for overall student learning and success, and it has implications for online classes versus actual classroom experiences.

How to directly apply these results to curriculum design and teaching is debatable. On one hand, if a high proportion of students use various motivation strategies and strive for grade or other targets, a teacher can improve student performance by designing science labs in ways that do not allow students opportunities for in-class self-regulated learning and motivating students with external incentives. However, advocates for transformation in science education are pushing in the opposite direction. The development of complete learners who can self-regulate and still be lifelong learners is a major goal of science educators in general (Advisory Committee to the Directorate for Education and Human Resources 1998, 277–311; Brewer and Smith 2011, 4–6; National Research Council 2003, 10–27). Furthermore, students have numerous other important aspects to their education that need to be considered, such as exams in other classes, papers in other classes, and extracurricular activities. This study examines only one goal: grades. How the freedom to choose whether to leave or stay relates to other class goals and other goals in general was not examined in this study. Thus, this is just a first step in investigating this question.

Results of this study also support the idea that students may utilize time-target strategies with various motivations when allocating their time to study. How students allocate time toward learning is typically covered in metacognitive theory examining the self-regulation of study. Recent metacognitive research dealing with student time allocation relative to simple or complex tasks has indicated students may use a time-limited strategy when confronting complex tasks, a prediction of the diminishing criterion model (Undorf and Ackerman 2017). If the results of this study accurately indicate student time-allocation strategies, it is possible to expand predictions of the diminishing criterion model to include student study strategies when they are allocating study time between classes differing in difficulty and value (five credit versus one credit).

In general, a theoretical framework for understanding student motivation strategies can have many applications. If students are using a motivation strategy, then a teacher may want to add lecture and discussion time to shift the student cost/benefit ratio and thus the student's time allocation. This technique has been successfully used in the transformation of classrooms from passive to active learning cultures (Freeman, Haak, and Wenderoth 2011). Also, the time investment in shifting student cost/benefit ratios relative to their motivation might be different for classes with different proportions of students varying in their motivation strategies. For instance, freshman-level courses that serve students with a variety of majors might have a completely different makeup relative to motivation strategies than would a senior-level upper-division class serving only discipline-specific majors. In such classes, the teacher may elect to spend less time "cheerleading" and more time with the specific learning goals. As

another example, for individual sections in a multiple-section class, class composition relative to motivation strategies is likely to vary stochastically and the variation may have implications for minor tweaks in teaching strategies. For example, classes with a high proportion of proficiency and time-limited students may have a completely different "personality" than those of classes with mostly grade-target students. The differences in personality could lead to differentiated teaching and slight adjustments in strategies between sections of a given class. Research on successful techniques for classes with different "personalities" could prove valuable.

ACKNOWLEDGMENTS

We thank members of the President's Teaching and Learning Collaborative for helpful discussions, and all the graduate student teaching assistants and students who participated in the research. Funding for this study was provided by the President's Teaching and Learning Collaborative at the University of Colorado at Boulder.

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