The Interactive Effects of Personal Achievement Goals and Performance Feedback in an Undergraduate Science Class

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The authors explored whether manipulating feedback influenced cognition, motivation, and achievement in an undergraduate chemistry course. They measured students’ ($N = 250$) achievement goals, test anxiety, self-efficacy, and metacognitive strategy use at the beginning and end of the semester. After completing the first set of questionnaires, students were randomly assigned to 1 of 4 conditions: (a) control, (b) mastery feedback, (c) performance-approach feedback, and (d) combined mastery/performance-approach feedback. In each condition, students received a raw performance score for each weekly quiz they completed online and, for the treatment conditions, additional feedback reflective of that specific feedback condition. Results provide evidence for the multiple goals perspective (specialized pattern) wherein performance-oriented feedback was beneficial for some outcomes, whereas mastery feedback was beneficial for other outcomes.

Keywords feedback, metacognition, personal achievement goals, self-efficacy, test anxiety
Dweck, 1986). Given Hulleman and colleagues’ (2010) comprehensive meta-analysis on the conceptualizations of achievement goals, we adopt their definition. Accordingly, achievement goals are defined as “a future-focused cognitive representation that guides behavior to a competence-related end state that the individual is committed to either approach or avoid” (Hulleman et al., 2010, p. 423).

Goal theorists conceptualize achievement goals within a trichotomous (e.g., Elliot & Church, 1997; Middleton & Midgley, 1997; Pintrich, 2000) or 2 × 2 achievement goal framework (Elliot & McGregor, 2001; Elliot & Murayama, 2008) that distinguish goals from a mastery-performance dichotomy and an approach-avoidance dichotomy. Within the trichotomous framework, three distinct achievement goal orientations have been proposed: mastery, performance-approach, and performance-avoidance. A mastery goal orientation (or mastery-approach orientation, as it is labeled in the 2 × 2 framework) describes individuals who strive to develop competence and task mastery. In contrast, a performance-approach goal orientation characterizes individuals who strive to demonstrate aptitude and seek favorable judgments; competence is self-evaluated in comparison to others. The third goal is a performance-avoidance orientation, whereby individuals strive to avoid appearing incompetent and avoid negative judgments. Like the performance-approach orientation, comparisons of competence are made with other individuals. Last, the 2 × 2 achievement goal framework adds a fourth goal orientation: mastery-avoidance orientation, whereby a learner’s goal is to avoid failure rooted in an intrapersonal perspective rather than in comparison to others. For the mastery-avoidance goal construct, avoiding incompetence is the focus (Elliot & McGregor, 2001). Because mastery-avoidance is a relatively new construct compared with the other three (Elliot, 1999), few studies have explored this orientation and little empirical work has been conducted to examine its psychometric properties (Hulleman et al., 2010). Moreover, given the negative relations between performance-avoidance goals and various outcomes (see Hulleman et al., 2010), we focused solely on mastery (approach) versus performance-approach goals at both the personal goals and induced goals levels (subsequently detailed).

As Hulleman and colleagues (2010) reported, the past 25 years of research on achievement goal theory has resulted in a number of theoretical frameworks, yet theorists generally agree that mastery goals and performance goals are two distinct ways to define competence. Traditionally, mastery goals were construed as having a positive association with adaptive motivational processes and outcomes, whereas performance goals were theoretically associated with less adaptive patterns of learning and motivation (Ames, 1992b). As evidence accumulated, results with respect to performance goals were mixed wherein some positive patterns were found and others were neutral or negative. On the basis of conflicting evidence, goal theorists reconceptualized performance goals into performance-approach and performance-avoidance goals, and began to identify ways in which performance-approach goals can combine with mastery goals to promote optimal motivation, cognition, and learning outcomes (Barron & Harackiewicz, 2001; Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002; Lau & Nie, 2008; Murayama & Elliot, 2009; Pintrich, 2000).

Today, researchers continue to explore conditions under which mastery goals, performance-approach goals, or a combination of the two result in better cognitive, motivational, and learning outcomes. In particular, while the theoretical distinction between the normative goals (or mastery goals) perspective and the multiple goals perspective (Hulleman et al., 2010) is clear, empirical work that examines these two perspectives continues. For example, some scholars theoretically
favor the mastery goals perspective and argue that adopting a mastery goal results in better motivational and learning processes and outcomes (Kaplan & Middleton, 2002; Midgley, Kaplan, & Middleton, 2001), such as higher levels of cognitive engagement, self-reported self-regulatory strategies (e.g., Pintrich, 2000), self-efficacy, interest, and value (e.g., Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000; Wolters, Yu, & Pintrich, 1996), and higher positive affect and lower negative affect (e.g., Kaplan & Maehr, 1999; Middleton & Midgley, 1997), to name a few. According to this perspective, mastery goals are adaptive given that mastery-oriented individuals are said to seek out challenge and persist in the face of difficulty. In contrast, they suggest that performance goals are typically maladaptive, which is supported by some evidence that shows that performance goals are negatively related to self-efficacy (e.g., Skaalvik, 1997) and positively related with negative affect and test anxiety (e.g., Kaplan & Maehr, 1999; Middleton & Midgley, 1997) and with avoidant help seeking (Ryan & Pintrich, 1998). In theory, these patterns are maladaptive given that individuals who adopt performance goals tend to avoid challenge (especially if they perceive themselves as low in competence), as challenges threaten the possibility of demonstrating ability and outperforming others (Dweck & Leggett, 1988). Moreover, rather than risk failure, they are likely to withdraw effort or give up in the face of challenge.

In contrast, the multiple goals perspective suggests that performance-approach goals do not always result in negative effects, even for individuals with low perceived competence. That is, the positive effects of mastery goals do not automatically result in negative performance-approach goal effects (Harackiewicz, Barron & Elliot, 1998). As several studies have demonstrated, performance-approach goals are also associated with positive outcomes such as effective cognitive engagement (e.g., Meece, Blumenfeld, & Hoyle, 1988), task value (Bong, 2001; Church, Elliot, & Gable, 2001), academic self-concept (Pajares, Britner, & Valiante, 2000), effort expenditure (Elliot, McGregor, & Gable, 1999) and achievement (Bouffard, Vezeau, & Bordeleau, 1998; Harackiewicz et al., 2000; Pintrich, 2000). Moreover, these theorists argue that mastery and performance-approach goals should not be construed as mutually exclusive (Harackiewicz et al., 1998); striving to outperform other students can be coupled with attempting to master a task. In this regard, adopting multiple goals of mastery and performance-approach may result in better learning outcomes (Barron & Harackiewicz, 2001; Pintrich, 2000). Central to the multiple goals perspective, then, is the notion that endorsing performance-approach goals can be beneficial, especially when mastery goals are concurrently endorsed (Harackiewicz et al., 2002).

From an educational reform perspective, it is important for researchers to determine which goals teachers should induce in a classroom context. Should teachers develop classroom environments that foster mastery goals, or should teachers develop classroom contexts that include elements of both mastery and performance-approach? Before attempting to answer this question, it is important to distinguish between induced goals in a learning situation and personal achievement goals (Harackiewicz & Barron, 2004). For example, students may come into a classroom situation with personally adopted goals that may interact with situationally induced or manipulated goals (Harackiewicz et al., 1998; Murayama & Elliot, 2009). Accordingly, it is important to consider both personal achievement goals as well as the contextual factors that may induce achievement goals (e.g., type of feedback received, instructions given, or statements made by teachers during lecture; Barron & Harackiewicz, 2001; Linnenbrink, 2005). We question which goal or combination of goals results in better learning outcomes and under which types of classroom conditions.
The purpose of this research was to further empirically evaluate the mastery versus multiple goals perspective in the context of an authentic classroom-learning situation. Following Harackiewicz and colleagues’ (1998) recommendations, because learners may adopt multiple goals, we evaluated the effects of personal and manipulated goals (induced through feedback) and their potential interactions on multiple outcomes. Specifically, we examined whether manipulating feedback influenced students’ test anxiety, and altered their personal mastery and performance-approach goals, academic self-efficacy, self-reported use of metacognitive self-regulatory strategies, and academic achievement in the context of a first-year undergraduate chemistry course. We examine how three feedback conditions used to induce specific types of achievement goals (mastery, performance-approach, combined mastery/performance-approach) relate to students’ motivation and affect, learning strategies, and achievement. In the sections that follow, we explore the multiple goals perspective and related empirical work to provide a basis from which to develop specific testable hypotheses.

The Multiple Goals Perspective

As previously noted, although some studies have found that performance-approach goals can have detrimental effects on learning, proponents of the multiple goals perspective assert that performance-approach goals can also have positive effects on motivation, learning, and achievement. That is, performance-approach goals may be adaptive under certain situations, and may be particularly adaptive when adopted in conjunction with a mastery goal. Moreover, several researchers have found that mastery and performance-approach goals are positively related (e.g., Archer, 1994; Harackiewicz, Barron, Carter, Lehto, & Elliot, 1997), suggesting that students can and do pursue multiple goals and that these goals may interact and combine to promote motivation and achievement.

According to Harackiewicz and colleagues (Barron & Harackiewicz, 2001; Harackiewicz et al., 2002), to test the multiple goals perspective requires considering multiple outcomes along with tests of independent and interactive effects of mastery and performance-approach goals on each of those outcomes. Specifically, they proposed four ways in which performance-approach and mastery goals may combine. First, the additive effect occurs when each goal is independently beneficial for a single outcome, which results in positive main effects for mastery and performance-approach goals. Second, the interactive effect occurs when the adoption of both goals is more adaptive than adopting one goal alone for an outcome, which results in a positive Mastery × Performance-Approach interaction. For both of these effects, students who adopt both goals will have the most adaptive outcomes. That is, if the effects are additive, then positive effects of performance-approach goals do not depend on a high level of mastery goals. In contrast, for the interaction effect, positive performance-approach goals do depend on a high level of mastery goals (Harackiewicz et al., 2002).

The third pattern, specialized effects, occurs when there are unique effects of each goal across multiple outcomes. That is, rather than promoting the same educational outcome, mastery and performance-approach goals affect different outcomes. In this case, a positive main effect for mastery goals on one outcome is found whereas a positive main effect for performance-approach on a different outcome would support the specialized effects pattern. Last, selective effects refer to situations where learners focus on the goal orientation that is most relevant in a particular context or learning situation. For example, a student may adopt mastery goals when given a writing
assignment, but then switch to adopt a performance-approach goal when given a multiple-choice exam. Empirical evidence of this pattern requires multiple time points and multiple outcomes to demonstrate a mix of positive main effects and/or interactions between each type of goal across the various outcomes (Harackiewicz et al., 2002).

In contrast with the multiple goals perspective, the normative goals perspective would predict positive main effects for mastery goals and null or negative effects for performance-approach goals. In this regard, students who adopt high mastery goals and low performance-approach goals should result in the most adaptive pattern, whereas students who adopt high mastery and performance-approach goals will experience a depression of the positive effects of the mastery goals as a result of the adoption of high performance-approach goals.

Research that has evaluated the mastery versus multiple goals debate has explored the effects of personal (i.e., self-set) achievement goals on outcomes such as motivation, affect, strategy use and performance (e.g., Pintrich, 2000), cognitive, emotional, and achievement outcomes (e.g., Daniels et al., 2008), and interest and academic achievement (e.g., Harackiewicz et al., 2002). Researchers have also examined the effects of manipulated goals on intrinsic motivation (e.g., Harackiewicz & Elliot, 1993), or a combination of personal and manipulated achievement goals on various outcomes (e.g., Linnenbrink, 2005).

In particular, previous research with samples of undergraduate students has investigated whether achievement goals predict the four variables of interest in the present study: metacognitive strategies, test anxiety, self-efficacy, and academic achievement. Specifically, mastery goals tend to negatively predict test anxiety (Bandalos, Finney, & Geske, 2003) but positively predict metacognitive strategies (Muis & Franco, 2009; Pintrich, 2000; Wolters et al., 1996) and self-efficacy (Bandalos et al., 2003; Coutinho & Neuman, 2008), whereas performance-approach goals tend to negatively predict metacognitive strategies (Muis & Franco, 2009) but positively predict academic achievement (Curry, Elliot, Da Fonseca, & Moller, 2006; Senko & Harackiewicz, 2005), self-efficacy (Bandalos et al., 2003; Coutinho & Neuman, 2008), and test anxiety (Bandalos et al., 2008; Pekrun, Elliot, & Maier, 2009).

As such, the conceptualization of achievement goals as antecedents to academic achievement, test anxiety, and metacognitive strategies is clear; however, the directionality between goals and self-efficacy is less clear. In the literature, self-efficacy has been reported as a precursor to personal goals (Liem, Lau, & Nie, 2008; Wigfield, 1994) and as an outcome to personal goals (Bandalos et al., 2003; Coutinho & Neuman, 2008). Since self-efficacy is based on past performance and predicts future performance, and performance itself is predicted by personal goals (Bandura, 1993), it is reasonable to examine self-efficacy as either an antecedent or a consequence of achievement goals. For the present study, we adopt the latter.

As Harackiewicz and colleagues (1998) suggested, when examining relations between achievement goals and various outcomes, it is important to consider both personal achievement goals as well as situationally induced goals that may be established in a classroom or learning context. Specifically, as Harackiewicz and colleagues highlight, it is pertinent to distinguish between personal goals and induced goals, as there is not necessarily a one-to-one correspondence. Rather, these two types of goals may interact in ways that influence various outcomes. For example, Harackiewicz and Sansone (1991) proposed that achievement goals are most effective when an individual’s personal goals match those of the learning context, like the type of environment a teacher establishes in his or her classroom.
ACHIEVEMENT GOALS AND PERFORMANCE FEEDBACK

Of particular interest, several studies have examined how students’ personal achievement goals are influenced by situational goals, and how these interact and relate to self-efficacy, self-regulatory skills, engagement, interest, effort withdrawal, avoidance coping, intrinsic motivation, academic self-concept, and achievement (Lau & Nie, 2008; Linnenbrink, 2005; Murayama & Elliot, 2009). To date, results have been mixed and theorists have proposed why students might respond differentially depending on the learning context. For example, Murayama and Elliot (2009) proposed three ways in which personal and situational goals may interact to influence achievement-related outcomes. The first is what they call the direct effect, wherein classroom goal structures directly influence relevant outcomes even after the effects of personal goals are considered. The second is the indirect effect, wherein classroom goals indirectly influence outcomes through personal achievement goals. Last, the third model they propose is the interaction effect, wherein classroom goals moderate the influence of personal achievement goals on outcomes.

From a slightly different perspective, Linnenbrink and Pintrich (2001) proposed two competing hypotheses with regard to how classroom goals and personal achievement goals interact: the buffering hypothesis, and the matching hypothesis. For the buffering hypothesis, they propose that a personal mastery goal or mastery-oriented context will buffer the negative effects of personal performance-approach goals. In contrast, the matching hypothesis suggests that goals established in the learning context that match students’ personal goals are most beneficial in terms of a variety of learning outcomes. To test these two competing hypotheses, Linnenbrink (2005) examined the effects of a quasi-experimentally manipulated classroom goal condition (mastery, performance-approach, and a combined mastery/performance approach) and personal goal orientations on motivation, help-seeking, emotional well-being, cognitive engagement, and achievement with a sample of upper-year elementary students. To objectively create the different classroom goal conditions, Linnenbrink altered the general classroom goal structure as well as the specific type of feedback that students received in small groups. The mastery goal condition focused on learning and improvement, whereas the performance-approach goal condition emphasized the importance of demonstrating individual and group competence. For the combined mastery and performance-approach condition, the classroom and feedback given to students in their groups incorporated both elements of the mastery and performance-approach conditions.

At posttest, Linnenbrink (2005) found that students in the mastery condition reported higher personal mastery goals than students in the performance-approach condition. Similarly, at posttest, students in the performance-approach condition reported higher personal performance-approach goals than students in the mastery goal condition. Moreover, students’ personal goals at the beginning of the school year did not influence posttest outcomes, providing no support for the buffering or matching hypothesis. It is interesting that the combined mastery/performance approach classroom goal condition had the greatest positive influence on achievement and help seeking.

To interpret this outcome, Linnenbrink (2005) proposed that because students were placed into small groups to create the various types of classroom goal conditions, the effects might have been a function of grouping. That is, consistent with Deutsch’s (1949a, 1949b) research, students may have benefitted from being in groups; more engagement, more adaptive patterns of learning, and more social interactions are expected within a group when competing against other groups (between-group competition) as compared with when individuals are competing against each other within a group (within-group competition). Accordingly, one important question to address is whether similar beneficial patterns of outcomes are replicated when individuals are learning
independently in a more authentic learning situation, and whether this pattern is replicated at the undergraduate level of education. Our study responds to this call.

The Present Study

Our primary research question addresses the mastery goals versus multiple goals perspective: What learning context (mastery, performance-approach, or combined mastery/performance-approach) is more beneficial for reducing test anxiety and for promoting self-efficacy, cognitive engagement (e.g., metacognitive self-regulation), and achievement? To address this question, we manipulated feedback to induce specific achievement goals using an online quiz-taking environment in accordance with Ames’ (1992a, 1992b) TARGET framework. Ames (1992a, 1992b) identified six dimensions of a learning environment that may communicate messages about motivation and achievement, and may influence the types of personal goals that students adopt: tasks, authority relations, recognition, grouping procedures, evaluation, and timing (TARGET). Similar to personal achievement goals, the feedback given to students can also be described in terms of an orientation toward mastery or performance. For example, mastery feedback focuses on student mastery and self-improvement through tasks that involve variety and diversity, and recognition and evaluative feedback that focuses on individual effort (to name a few of Ames’ [1992a, 1992b] dimensions). In contrast, performance-approach evaluative feedback focuses on student competition and high achievement. Each of these types of feedback may influence the types of goals that students adopt in a learning context (Harackiewicz et al., 1998).

After completing a set of pretest questionnaires, undergraduate chemistry students were randomly assigned to one of four feedback conditions: a control condition, a mastery condition, a performance-approach condition, and a combined mastery/performance-approach condition. In each condition, students received their actual raw performance score for each of the 14 weekly quizzes they completed online and, for the treatment conditions, additional feedback reflective of that specific feedback condition. At the end of the semester, students completed a set of posttest questionnaires and their final grades were collected as a measure of academic achievement.

Following Linnenbrink (2005), we present two plausible hypotheses, one for each of the positions on goal adoption. First, from the mastery goals perspective, students in the mastery feedback condition will benefit most across all outcomes, whereas students in the performance-approach and combined conditions will not benefit given the detrimental effects of performance-approach goals. In this regard, we expect positive main effects for the mastery condition, but neutral or negative main effects for the performance-approach and mixed conditions. Alternatively, from the multiple goals perspective, three plausible outcomes may occur: the additive effect, the interactive effect, or the specialized effect. The additive effect would result in positive main effects for mastery and performance-approach goals on the same outcome. The interactive effect results when there is a positive mastery \( \times \) performance-approach interaction on the same outcome. Last, the specialized effect occurs when there is a positive main effect for mastery goals on one outcome whereas a positive main effect for performance-approach goals results on a different outcome.

Moreover, we measured students’ personal achievement goals at the beginning of the semester and then again at the end of the semester to assess whether students’ personal achievement goals changed as a function of their learning context and whether personal goals moderated the effects of the situationally induced goals to test the buffering versus the matching hypothesis. Accordingly, our second research question was: How do students’ personal achievement goal orientations
change and interact with situationally induced achievement goals? If the buffering hypothesis is correct, then students in the mastery condition should maintain their level of personal mastery goals, performance-approach goals should decrease, and these individuals should have the greatest benefit compared with the other groups. In contrast, if the matching hypothesis is correct, then personal achievement goals should moderate the effects in each of the manipulated conditions: students who adopt personal mastery goals at the beginning of the semester should have greater benefits in the mastery condition than students who adopt personal performance-approach goals, and vice versa for the performance-approach condition. Last, those in the combined condition should have equal benefits as both goals are induced in that condition.

METHOD

Participants

Participants were 250 (151 female, 99 male) undergraduate university students consented to participate in the study. Students were enrolled in a prerequisite qualifying first-year general chemistry course for science majors. The average age was 20.10 ($SD = 4.65$) and 65% of the sample was majoring in biology, biochemistry, or chemistry.

Materials

Prior knowledge

To measure prior knowledge of course content, participants completed a prior knowledge test. This 10-item multiple-choice test measured students’ knowledge of various chemistry concepts including properties of matter, electron configurations, chemical reactions, and stoichiometry (see Appendix A).

Personal achievement goals

To assess students’ personal mastery and performance-approach goal orientations, we used the student version of the Patterns of Adaptive Learning Scales (Midgley et al., 2000). It is a 14-item Likert-scale instrument designed to measure personal achievement goals within a trichotomous framework (i.e., mastery-avoidance goals are not measured); we chose it because it has demonstrated good psychometric qualities with similar samples (see Muis, Winne, & Edwards, 2009). We assessed mastery goals with items such as “One of my goals in chemistry class is to learn as much as I can.” Performance-approach goals were assessed with items such as “One of my goals is to show others that I’m good at my chemistry class work.” Items on the Patterns of Adaptive Learning Scales are anchored along a 5-point scale ranging from 1 (not at all true) to 5 (very true).

Self-efficacy, test anxiety, and metacognitive self-regulation

Items from the self-efficacy, test anxiety, and metacognitive self-regulation subscales of the Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, & McKeachie, 1991)
were used. The questionnaire is a widely used 81-item self-report measure designed to assess undergraduate students’ use of varying learning strategies and motivational orientations for an undergraduate course. The self-efficacy for learning and performance subscale comprises eight items and assesses expectancy for success and self-efficacy. Expectancy for success refers specifically to task performance, and self-efficacy includes judgments of one’s ability to successfully complete a task as well as one’s confidence in one’s skills to perform that task. Example items include “I believe I will receive an excellent grade in this class” (expectancy for success) and “I’m confident I can learn the basic concepts taught in this course” (self-efficacy). The test anxiety subscale includes five items that measure a student’s level of anxiety for learning course content and taking course exams. One example is “I have an uneasy, upset feeling when I take an exam.” Last, the metacognitive self-regulation subscale includes twelve items that measure processes of planning, monitoring and regulating cognitive activities. An example item is “When studying for this course I try to determine which concepts I don’t understand well.” Students rate each statement on a 7-point Likert scale ranging from 1 (not at all true of me) to 7 (very true of me). For all of these subscales, higher scores indicate greater agreement and thus greater strategy use.

**Achievement**

We measured achievement using the overall course raw score, which was then converted into a percentage (out of 100). This measure was computed as a nonweighted compilation of grades from three exams, a final exam, a cumulative online quiz score, laboratory work, and a cumulative in-class quiz score.

**The Learning Environment and Feedback Conditions**

Students enrolled in this course attended face-to-face lectures and labs, and were required to complete 14 weekly quizzes online (quizzes began in the second week of a 15-week semester). Instruction was primarily lecture-based, but the delivery was interactive and included informal, formative assessment with feedback. The instructor’s goal was to develop a mastery-oriented classroom and lab context for learning, and her philosophy was student-centered, supportive, and focused on individual achievement. For example, she used a small group problem solving strategy during nearly every session. During these problem-solving sessions, students worked cooperatively in heterogeneous groups of their own choosing to solve a well-structured problem provided by the instructor. Problem solutions were submitted and graded as a group quiz wherein everyone in the group who was present received the same grade. The instructor used this strategy as a mechanism for improving student learning and retention of the material, as well as the opportunity to improve teamwork skills.

Course evaluation consisted of scores from three midterm exams, online quizzes, group quizzes, laboratory work, and a final examination. Online content was provided through a commercial courseware system and was intended as a communication medium among students and the instructor, as an access point for the quizzing system, and as a reference location for notes, homework assignments, extra practice problems, and solution sets. Each feedback condition (mastery, performance-approach, combined mastery/performance-approach, control condition) was established using this system. Each week, students were required to complete a well-structured,
multiple-choice content quiz (online only). Quiz questions were developed using Bloom’s Taxonomy to target application, synthesis, and evaluation levels of understanding. At any point during the week, students had access to their quiz answers and could modify their responses at any time. At the end of each week, quizzes were graded and students were given their actual achievement score (a raw score out of 10, one point for each correct answer). If a score of at least 8 points out of 10 was not achieved, students were given the opportunity to complete a make-up quiz, which was available for four days following the original quiz. Moreover, based on the condition under which students were randomly assigned, each goal condition received additional feedback about their quiz performance (with the exception of the control condition). In all other aspects, the online content was identical.

Goal conditions were created via the type of feedback that students received on each weekly quiz. Following Linnenbrink’s (2005) protocol, and in line with the evaluation dimension of Ames’ (1992a, 1992b) TARGET framework, feedback in the mastery goal condition \((n = 68)\) emphasized the importance of learning, understanding, and improvement. For example, each week, students in the mastery condition were provided textual information regarding the elements noted above along with graphical information that indicated how much they improved (or did not improve) on that week’s assessment compared with previous weeks. In contrast, feedback in the performance-approach condition \((n = 78)\) included textual messages that emphasized the importance of demonstrating individual competence, with a particular emphasis on competition for high scores. Students in this condition were also provided performance feedback in graphical form that indicated how well they performed compared with other students. Moreover, their percentile rank was provided. Feedback in the combined mastery/performance-approach condition \((n = 52)\) included elements of both the mastery and performance-approach conditions, with an emphasis on doing better than others and trying to learn and understand. For this condition, students were provided textual and graphical information on their improvement from week to week as well as how well they performed compared with others. Percentile rank was also provided. Last, with the exception of a single performance score for each quiz, the control condition \((n = 52)\) received no additional feedback. Scores were not compared with previous weeks’ scores or to other students’ scores. Feedback for all other course assignments and exams, available through WebCampus, were reported as a raw score.

Procedure

Students were randomly assigned to one of the four conditions: mastery feedback, performance-approach feedback, combined mastery/performance-approach feedback, and a control group. Within the first week of the course, and prior to any assessments, students completed a demographics questionnaire, a prior knowledge test, and items from the Patterns of Adaptive Learning Scales and the Motivated Strategies for Learning Questionnaire. Over the course of the semester, students received weekly feedback about their performance on the weekly quizzes in the manner described previously. After quizzes were graded, feedback was automatically displayed upon login to ensure students received their performance evaluation. At the end of the semester, before students completed the final exam, we asked them to complete the Patterns of Adaptive Learning Scales and the Motivated Strategies for Learning Questionnaire items again.
TABLE 1
Descriptive Statistics and Reliability Coefficients for All Variables

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<thead>
<tr>
<th></th>
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<th>Posttest</th>
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<td>SD</td>
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<td>Final grade (%)</td>
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<td>.86</td>
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a1–7 scale.
b1–5 scale.
cSignificant difference (pretest to posttest) at the .01 or lower level.

RESULTS

Preliminary Analyses

All means, standard deviations, and reliability coefficients are presented in Tables 1 through 4 for all variables at pretest and posttest, and correlations between all variables are presented in Table 5. Using a series of one-way analyses of variance, we then explored whether there were any treatment group differences at pretest on prior knowledge, high school GPA, self-efficacy, test anxiety, metacognitive self-regulation, mastery goals, and performance-approach goals (see Table 2). Results revealed no differences between groups on any of these variables (all $p$s > .05). Moreover, no gender differences were found on any of the pretest variables (all $p$s > .05), so gender differences were not explored across outcomes.

Effects of Personal Achievement Goals and Feedback Condition on Outcomes

To explore our two main research questions at the multivariate level, we examined the effects of personal achievement goals and feedback on students’ academic performance (final grade), self-efficacy, test anxiety, and metacognitive self-regulation. We conducted an overall repeated measures multivariate analysis of variance with (pretest) personal mastery goals and personal performance-approach goals as moderators, feedback condition (control, mastery, performance-approach, and mastery/performance-approach) as the between-subjects independent variable, time as the within-subjects variable (pretest-posttest), and self-efficacy, test anxiety, and metacognitive self-regulation as the dependent variables (pretest-posttest). We conducted a separate analysis of variance for achievement given that achievement (grade) was measured at only one time.
### Table 2
Descriptive Statistics for Prior Knowledge, GPA, and Final Grade, by Condition

<table>
<thead>
<tr>
<th>Prior knowledge</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>52</td>
<td>3.44</td>
<td>2.02</td>
</tr>
<tr>
<td>Mastery</td>
<td>68</td>
<td>3.37</td>
<td>1.67</td>
</tr>
<tr>
<td>Performance</td>
<td>78</td>
<td>3.27</td>
<td>1.64</td>
</tr>
<tr>
<td>Combined</td>
<td>52</td>
<td>3.29</td>
<td>1.96</td>
</tr>
<tr>
<td>High school GPA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>50</td>
<td>3.69</td>
<td>0.48</td>
</tr>
<tr>
<td>Mastery</td>
<td>62</td>
<td>3.58</td>
<td>0.53</td>
</tr>
<tr>
<td>Performance</td>
<td>75</td>
<td>3.74</td>
<td>0.46</td>
</tr>
<tr>
<td>Combined</td>
<td>50</td>
<td>3.69</td>
<td>0.48</td>
</tr>
<tr>
<td>Final grade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>52</td>
<td>73.02a</td>
<td>14.69</td>
</tr>
<tr>
<td>Mastery</td>
<td>68</td>
<td>74.81</td>
<td>13.20</td>
</tr>
<tr>
<td>Performance</td>
<td>78</td>
<td>79.43a</td>
<td>11.67</td>
</tr>
<tr>
<td>Combined</td>
<td>52</td>
<td>75.74</td>
<td>14.62</td>
</tr>
</tbody>
</table>

*Note:* Significant difference at the .01 or lower level.

Using Pillai’s Trace, a significant omnibus $F$ for was obtained for time, $F(1, 244) = 7.09$, $p < .01, \eta^2 = .07$, scale (differences across each of the dependent variables), $F(2, 244) = 5.22$, $p < .01, \eta^2 = .04$, and feedback, $F(3, 244) = 3.21, p < .01, \eta^2 = .05$. Moreover, mastery goals and performance-approach goals moderated the effects over time, $F(1, 244) = 4.32, p < .05, \eta^2 = .02$, and $F(1, 244) = 7.83, p < .01, \eta^2 = .03$, scale, $F(2, 243) = 6.52, p < .01, \eta^2 = .05$.

### Table 3
Descriptive Statistics for Self-Regulated Learning Variables, by Condition

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Pretest</th>
<th></th>
<th>Posttest</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Self-efficacy$^*$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>52</td>
<td>5.70</td>
<td>.90</td>
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<td>1.24</td>
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<tr>
<td>Mastery</td>
<td>68</td>
<td>5.78</td>
<td>.91</td>
<td>5.62</td>
<td>.99</td>
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<tr>
<td>Performance</td>
<td>78</td>
<td>5.74</td>
<td>.97</td>
<td>5.05</td>
<td>1.30</td>
</tr>
<tr>
<td>Combined</td>
<td>52</td>
<td>5.41</td>
<td>1.13</td>
<td>5.33</td>
<td>1.08</td>
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<tr>
<td>Metacognitive self-regulation$^*$</td>
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<td></td>
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<tr>
<td>Control</td>
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<td>5.04</td>
<td>.84</td>
<td>4.79</td>
<td>.83</td>
</tr>
<tr>
<td>Mastery</td>
<td>68</td>
<td>4.87</td>
<td>.87</td>
<td>4.75</td>
<td>1.04</td>
</tr>
<tr>
<td>Performance</td>
<td>78</td>
<td>5.06</td>
<td>.86</td>
<td>4.71</td>
<td>.97</td>
</tr>
<tr>
<td>Combined</td>
<td>52</td>
<td>4.98</td>
<td>.88</td>
<td>4.96</td>
<td>1.01</td>
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<tr>
<td>Test anxiety</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>52</td>
<td>3.93</td>
<td>1.22</td>
<td>4.22</td>
<td>1.36</td>
</tr>
<tr>
<td>Mastery</td>
<td>68</td>
<td>3.91</td>
<td>1.62</td>
<td>3.72</td>
<td>1.41</td>
</tr>
<tr>
<td>Performance</td>
<td>78</td>
<td>3.96</td>
<td>1.18</td>
<td>4.32</td>
<td>1.11</td>
</tr>
<tr>
<td>Combined</td>
<td>52</td>
<td>4.23</td>
<td>1.48</td>
<td>4.32</td>
<td>1.38</td>
</tr>
</tbody>
</table>

*Note:* $^*$ All variables were reported on a 1–7 scale.
and $F(2, 243) = 8.02, p < .001, \eta^2 = .06$, and feedback, $F(1, 244) = 9.36, p < .01, \eta^2 = .04$, and $F(1, 244) = 10.99, p < .001, \eta^2 = .05$, respectively.

These results suggest that the feedback condition had a significant effect on student outcomes, and that these effects were moderated as a function of the level of students’ mastery and performance-approach goals at the beginning of the semester. Accordingly, follow-up repeated measures analyses were conducted for each dependent variable to explore in more detail the pattern of results to test the mastery versus multiple goals perspective.

**Self-Efficacy**

For self-efficacy, the univariate analysis revealed a main effect for time, $F(1, 244) = 26.93, p < .01, \eta^2 = .03$, but no main effect for feedback and no significant time $\times$ feedback interaction, which suggests that students across all conditions had a similar level of decline in self-efficacy. Moreover, students’ mastery goals moderated change in self-efficacy from pretest to posttest, $F(1, 244) = 8.02, p < .005, \eta^2 = .03$, wherein higher levels of mastery goals were related to greater decreases in self-efficacy.

**Metacognitive Self-Regulation**

The univariate analysis for metacognitive self-regulation showed a main effect for time, $F(1, 244) = 7.82, p < .01, \eta^2 = .03$, and a significant time $\times$ feedback interaction, $F(3, 244) = 2.62,$
Moreover, both mastery and performance-approach goals moderated change in students’ metacognitive self-regulation over time, $F(1, 244) = 7.04, p < .01, \eta^2 = .03$, and $F(1, 244) = 7.61, \eta^2 = .03$ and mastery goals moderated the effect for feedback, $F(1, 244) = 20.99, p < .001, \eta^2 = .08$. In particular, the main effect for time revealed that students had self-reported higher levels of metacognitive strategy use at pretest compared with posttest, and that the rate of change was greater for individuals with higher levels of mastery and performance-approach goals. Moreover, these changes over time varied as a function of feedback. Follow-up analyses revealed that individuals in the control and performance conditions significantly dropped in metacognitive self-regulation compared with the other two groups ($p < .01$), which did not change ($p > .10$). For feedback, moderation analyses revealed that individuals with higher levels of mastery goals had greater rates of change than individuals with lower levels of mastery goals.

Test Anxiety

For test anxiety, unlike self-efficacy and metacognitive self-regulation, there was no main effect for time or feedback, but there was a significant moderation effect for performance-approach goals on feedback, $F(1, 244) = 19.28, p < .001, \eta^2 = .09$. In particular, students with higher levels of performance-approach goals at the beginning of the semester had higher levels of test anxiety (collapsed across time) compared with students who adopted lower levels of performance-approach goals. No other effects were found.

Academic Achievement

For achievement, the analysis of variance revealed a significant main effect for feedback, $F(3, 244) = 2.75, p < .05, \eta^2 = .03$, but no other significant effects were found. Post hoc analyses using the least significant difference procedure demonstrated that students in the performance-approach feedback condition had the highest level of achievement, which differed significantly from the control group ($p < .01$) and mastery group ($p < .05$). No other significant differences were found.

Effects of Feedback Condition on Students’ Entering Personal Achievement Goals

We conducted the last series of analyses to assess whether feedback influenced students’ entering personal achievement goals. Accordingly, we conducted a repeated measures analysis for each personal goal orientation (pretest-posttest) with feedback condition as the between-subjects independent variable. Means and standard deviations are presented in Table 5. For students’ personal mastery goals, using Pillai’s Trace, a significant main effect of time was found, $F(1, 246) = 9.95, p < .01, \eta^2 = .04$, but there was no significant effect of feedback and no interaction. In particular, collapsed across feedback group, students’ mastery goals decreased from the beginning to the end of the semester.

In contrast, for students’ personal performance-approach goals, there was a main effect for time, $F(1, 246) = 3.90, p < .05, \eta^2 = .02$, and a main effect for feedback, $F(1, 246) = 5.60, p < .05, \eta^2 = .03$, but no interaction. Over time, collapsed across feedback condition, students’ performance-approach goals significantly decreased. For the main effect for feedback, post hoc least significant difference analyses revealed that students in the mastery feedback condition had
significantly lower levels of performance-approach goals compared with all other groups (all $p < .05$). No other differences were found.

**GENERAL DISCUSSION**

The purpose of this study was to explore the effects of manipulating feedback on students’ personal achievement goals, motivation, self-reported strategy use and affect for learning science content, as well as their achievement in a first-year undergraduate chemistry course. Results from our study indicate that students’ self-reported levels of self-efficacy and metacognitive self-regulation decreased significantly over time and that these decreases were moderated by students’ mastery goals (for self-efficacy) and both mastery and performance-approach goals (for metacognitive self-regulation). Moreover, decreases in metacognitive self-regulation occurred only in the control and performance-approach feedback groups. In addition, students’ levels of test anxiety were moderated by performance-approach goals wherein individuals with higher levels of performance-approach goals also had higher levels of test anxiety. Last, for achievement, students in the performance-approach feedback group achieved the highest grades compared with the other groups. We discuss the theoretical and educational implications of these findings in the context of the various hypotheses that we tested for this research. We then conclude with limitations and directions for future research.

**The Normative versus Multiple Goals Perspective**

To examine these two theoretical positions, we explored whether students in a mastery-oriented feedback condition experienced more gains compared with students in a performance-approach condition, a combined mastery/performance-approach condition, and a control condition, and whether students’ personal entering goal orientations moderated the effects of the feedback.
ACHIEVEMENT GOALS AND PERFORMANCE FEEDBACK

conditions. The normative goals perspective predicts that students in the mastery feedback condition would have the greatest benefit across all outcomes compared with the other conditions. In contrast, the multiple goals perspective would predict additive effects, interactive effects, or specialized effects across the various outcomes.

Results from our study provide strong evidence for a specialized pattern of outcomes, which supports the multiple goals perspective. In particular, whereas students in the mastery feedback and combined conditions did not self-report lower levels of metacognitive strategy use at posttest, students in the performance-approach and control conditions reported significantly lower levels. These results are consistent with previous research that has found that mastery goals positively predict metacognitive strategy use (Muis & Franco, 2009; Pintrich, 2000; Wolters et al., 1996), whereas performance-approach goals negatively predict their use (Muis & Franco, 2009). We take this one step further and infer that the feedback students received in our study had a significant influence on students’ use of these strategies wherein mastery-oriented feedback served as a protective mechanism; students who received that feedback maintained their level of strategy use, whereas students who did not receive this type of feedback (e.g., they received normative information or no information) significantly lowered their use of these strategies.

In contrast, students who received normative feedback (e.g., performance-approach and combined conditions) had the highest levels of achievement compared with students who did not receive this type of feedback. This is also consistent with previous research that has demonstrated a positive relationship between performance-approach goals and academic achievement (Cury et al., 2006; Senko & Harackiewicz, 2005; Senko & Miles, 2008; Wolters et al., 1996). As Senko and Miles (2008) demonstrated, although mastery goals are associated with deep learning strategies and high course interest, mastery goals are rarely related to achievement. In contrast, performance-approach goals are associated with high levels of achievement, despite their relations to surface learning strategies and low interest. It is important to note that results from their study provide empirical evidence that mastery-oriented students, who were more interested in the course content, were likely to focus their studying on more interesting content, while ignoring the boring material. In comparison, performance approach–oriented students, who were not interested in the course content, were more likely to study more of the content, which resulted in higher grades.

In our study, when placed into a normative feedback condition, students performed well compared with others, regardless of their entering personal achievement goals. As such, consistent with Senko and Miles (2008), we infer that under noncompetitive learning conditions, mastery goals are not adaptive from an achievement perspective. However, when placed into a competitive environment, mastery-oriented individuals can reap the benefit of that competitive environment by focusing more on higher achievement outcomes. In this regard, it appears that performance-approach feedback elicits a positive influence on achievement.

On the basis of these results, as did Linnenbrink (2005), we interpret that performance-approach learning environments may be beneficial for some learning outcomes, like academic achievement, but not so beneficial for other outcomes like metacognitive strategy use. In the context of the types of feedback that students received in our study, we posit that a visual display of one’s performance over time can have important influences on students’ personal judgments of their competence. For example, for students in the mastery group, seeing one’s performance over time compared with others can provide valuable information with regard to learning outcomes. That is, feedback provides information about competence or incompetence, and goal orientation
influences how that information is interpreted (Bobko & Colella, 1994). In the face of negative feedback (e.g., receiving lower scores than others in the class), individuals with a mastery goal orientation may increase effort or revise tactics and strategies (Dweck & Leggett, 1988; Elliott & Dweck, 1988). In contrast, when presented with information about how well they are doing in comparison to others, individuals with high performance-approach goals are more likely to perceive negative information as evaluative or judgmental (Ames, 1992b). This evaluative information is likely threatening, resulting in negative affect like higher levels of anxiety (Elliot & Harackiewicz, 1996), which is what we also found in our study. In particular, students with higher performance-approach goals had higher levels of test anxiety.

Last, similar to Linnenbrink (2005), given the mixed results, our results do not provide clear support for the buffering or matching hypothesis. Although mastery-oriented individuals benefited from being in a mastery feedback condition for metacognitive self-regulation, this was not the case for their academic achievement or self-efficacy. Moreover, normative feedback benefitted all students in that particular condition, and students’ personal goals did not moderate the effect of that feedback, as one might expect with the matching hypothesis. This complex pattern of results suggests that perhaps other mechanisms or interactions are occurring that are not captured by either of these two hypotheses. We find this particularly noteworthy; as Linnenbrink suggested for her study, perhaps group dynamics interacted with the induced goal context. For our study, perhaps the interaction or complex patterns were a result of the content and quizzes that were available online. It is important to note that it is possible that the combination of more traditional in-class lecture, labs, and exams coupled with the online content and quizzes may have been an important factor that influenced the results of our study. To date, we do not know of any studies that have explored relations between these variables in a mixed environment such as the one described here. In this regard, there may be other important environmental factors that need to be explored in future work.

The Effects of Feedback on Personal Achievement Goals

Previous research that has examined the effects that learning environments have on students’ personal achievement goals, self-regulatory strategies, self-efficacy, intrinsic motivation, academic self-concept, and achievement has typically found that a combined mastery/performance-approach classroom goal orientation is related to students’ adoption of mastery and performance-approach goals (e.g., Church et al., 2001; Murayama & Elliot, 2009). Based on these previous studies, we hypothesized that students in the mastery feedback condition would experience increases in personal mastery goals and decreases in performance-approach goals, whereas students in the performance-approach feedback condition would experience decreases in mastery goals and increases in performance-approach goals. Last, we expected that students in the combined condition would experience increases in both mastery and performance-approach goals.

Results from our study only partially supported these hypotheses. Students in the mastery feedback condition had the lowest level of performance-approach goals compared with the other groups. However, regardless of their feedback condition, all students experienced significant decreases in their mastery and performance-approach goals over time. From a goal stability perspective, we find these results particularly noteworthy. That is, recent studies that have examined the stability of undergraduate students’ achievement goal orientations have found significant decreases in students’ mastery goals (e.g., Fryer & Elliot, 2007; Muis & Edwards, 2009; Senko &
Harackiewicz, 2005) and performance-approach goals (Senko & Harackiwicz, 2005). From these studies, one may infer students’ mastery goals decrease over the course of the semester, even in classrooms that are primarily mastery oriented (Muis & Edwards, 2009). However, we also note that, in our study, students’ initial mastery goals level was quite high (the mean was 4.70), with little opportunity to move upward. Alternatively, perhaps students initially report an ideal with regard to what goals they would like to adopt for their course, an ideal that changes as that course becomes a reality. Of course, these are merely speculative ideas; ones that require further empirical scrutiny. Either way, these results have important educational implications, which we discuss next.

**Educational Implications**

Given increasing demands for scientists (National Science Board, 2006) and the growing concerns of the dropout rates for undergraduate students enrolled in the sciences (Daempfle, 2004), it is pertinent that educators implement classroom interventions that foster student learning, motivation, and achievement in science. We responded to this pressing concern by implementing a system that manipulated the types of feedback students received on their online course quizzes. Our goal was to create different feedback environments that mirrored the types of classroom goal structures that researchers suggest might foster improved learning, motivation, and achievement. By creating environments that focus on varying feedback, we aimed to increase student cognition, motivation, and achievement in a first-year undergraduate chemistry course.

Because of the positive outcomes with regard to metacognitive self-regulation with the mastery goal condition, and the positive effects with regard to achievement for the performance-approach condition, we posit that our intervention is a positive first step toward developing effective interventions designed to address student achievement at the undergraduate level of education. Specifically, provincially or state-funded colleges and universities across North America typically have large first-year undergraduate enrollments in the sciences and mathematics. Given the large number of students in these courses, it is particularly challenging for professors to provide immediate feedback and feedback that provides more than raw score information. In a time of budget cuts and reductions in teaching assistantships, professors are left to grapple with large amounts of grading and little time to complete it. By implementing a system that provides students with immediate feedback on their performance coupled with information that focuses on understanding and improvement, comparative performance, or both, there is more opportunity for students to learn from that immediate feedback, which may subsequently improve student outcomes (Muis, 2007; Winne & Hadwin, 1998).

**Limitations and Future Directions**

Although some interesting patterns of results emerged from our research, results must be interpreted with caution, as there are a number of limitations that need to be addressed. First, it is pertinent to assess the effectiveness of the intervention in future studies. In particular, we plan to assess treatment fidelity by directly asking students about the nature of the feedback they received, their perceptions about that feedback, and whether and how the feedback influenced their thinking about their own learning. By better understanding whether and how students attended to
the feedback, researchers may be able to develop instructional interventions that more effectively address students’ needs in terms of bolstering their learning, motivation, and achievement.

In addition, future studies could examine different dimensions of classroom goal structures to assess whether some dimensions are more effective than others with regard to influencing students’ cognition, motivation, and academic achievement. In the present study, by manipulating feedback structures, we focused on one dimensions of Ames’ (1992a, 1992b) TARGET system: the evaluation dimension. Results from our study suggest that attending to this dimension of the classroom goal structure can lead to changes in students’ personal goals, self-efficacy, test anxiety, metacognitive self-regulation, and achievement. However, given the modest effect sizes associated with these changes, we wonder if there are other dimensions that may have a greater effect on student outcomes. That is, how would results have differed if our intervention focused on manipulating different dimensions of the TARGET framework, such as authority relations? If educators could only feasibly enhance only one or two dimensions of their classroom goal structures, which dimensions should they focus on? We anticipate exciting new directions along this line of work not only with students enrolled in science courses, but also for students enrolled in other courses from other disciplines including mathematics and the social sciences.

**AUTHOR NOTES**

Dr. Krista R. Muis is an Associate Professor at McGill University in the Department of Educational and Counselling Psychology. Her research interests are in the areas of self-regulated learning, epistemic beliefs, achievement motivation, emotions, and mathematics and science learning. She is interested in how students’ epistemic beliefs and emotions influence various facets of learning, motivation, and academic performance. She also examines how teachers’ beliefs about knowledge and knowing influence their practices and how those practices affect student outcomes. Moreover, all lines of research are brought together under contemporary models of self-regulated learning. John Ranellucci is a Ph.D. candidate in the Learning Sciences Program at McGill University. He is interested in achievement goals and emotions, and is exploring the effects of an intervention designed to address interest-based learning in mastery-oriented individuals. Dr. Gina M. Franco completed her Ph.D. under the supervision of Dr. Muis at McGill University. She is interested in the role of epistemic beliefs in students’ learning and conceptual change. Dr. Kent J. Krippen is an Associate Professor in STEM Education at the University of Florida. His research interests include the development and use of technology to improve instruction and maximize learning.

**REFERENCES**

Achievement goals and performance feedback


APPENDIX

Prior Knowledge Questionnaire

1. An increase in the temperature of a solution usually . . . {Solutions}
   decreases the solubility of a solid solute in the solution.
   Increases the boiling point.
   Decreases the solubility of a liquid solute in the solution.
   Increases the solubility of a gas in the solution.
   * increases the solubility of a solid solute in the solution.

2. The correct answer for the addition of 7.5 g + 2.26 g + 1.311 g + 2 g is______. {Significant Figures}
   13.071 g
   * 13 g
   13.0 g
   10 g
   13.1 g

3. A pure substance is matter with a composition that . . . {Properties of Matter}
   always contains oxygen
   • is fixed in a definite proportion at all times
   always contains two or more substances
   varies according to the amount of water present
   depends on the temperature
4. Identify the metalloid in the following list. {Periodic Table}
- sulfur (S)
- germanium (Ge)
- silver (Ag)
- copper (Cu)
- fluorine (F)
5. The abbreviated electron configuration for a boron atom (Z = 5) is ______. {Electron Configuration}
- [He] 2s² 2p¹
- 1s² 2s² 2p¹
- [Ne] 2s² 2p¹
- [H] 2s² 2p¹
- 1s² 2s² 2p⁶
6. Gold (III) bromide has the following correct formula. {Formula Writing}
- Au³Br
- AuBr³
- AuBr²
- AuBr
- * Au³Br³
7. What is the coefficient of hydrogen, H₂, when the following equation is balanced? {Chemical Equations}
- Al + H₂SO₄ → Al₂(SO₄)₃ + H₂
- 3
- 5
- 2
- 1
- 4
8. The following reaction is an example of a ______ reaction. {Chemical Reaction Types}
- 2C₂H₆ + 7O₂ → 4CO₂ + 6H₂O
- single replacement
- decomposition
- double replacement
- displacement
- * combustion
9. When 2.50 mol of Mg₃N₂ are allowed to react according to the following equation, how many moles of H₂O also react? {Stoichiometry}
- Mg₃N₂ + 6H₂O → 3Mg(OH)₂ + 2NH₃
- 1.25 mol
- 2.50 mol
- 9.00 mol
- * 15.0 mol
- 6.00 mol
10. The volume of a gas with a pressure of 1.2 atm increases from 1.0 L to 4.0 L. What is the final pressure of the gas, assuming constant temperature? {Gas Laws}
- 1.0 atm
- 1.2 atm
- 4.8 atm
- 3.3 atm
- * 0.30 atm