Science Diaries: A Brief Writing Intervention to Improve Motivation to Learn Science

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This study investigated the hypothesis that prompting students to self-assess their interest and understanding of science concepts and activities would increase their motivation in science classes. Students were randomly assigned to an experimental condition that wrote self-assessments of their competence and interest in science lessons or a control condition that wrote summaries of those same lessons. Writing activities were 10 minutes long and were given approximately once a week for eighteen weeks. Student motivation was assessed via self-report surveys for achievement goals and interest in science before and after the intervention. Students in the experimental condition showed higher endorsement of mastery goals and reported greater situational interest in science topics after the intervention compared to students who summarized the lessons. Increases in situational interest predicted higher individual interest in the domain. Results indicate an instructional practice requiring just three hours out of a semester of instruction was sufficient to achieve these effects on motivation in science classes.

KEYWORDS: Self-assessment, reflective writing, mastery goals, interest, science instruction

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Results of a recent international study on science education and achievement have shown that US students perform poorly compared to students in Asian countries on measures of motivation and achievement in science (Gonzales, Williams, Jocelyn, Roey, Katsberg, & Brenwald, 2008). Research has revealed much about the nature of motivation and achievement and can be leveraged to address this issue. The purpose of this study is to build upon prior research on motivation to create an instructional intervention that helps to promote motivation in science. In this study, we focus on two related motivational constructs known to affect learning: achievement goals and interest.

Over the past 25 years, research has revealed many important relationships between student learning, and motivational constructs such as achievement goals (Ames, 1992; Elliot & Church, 1997; Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002), stereotype threat (Aronson, Fried, & Good, 2002), self-concept (Cohen, Garcia, Apfel, & Master, 2006), student interest (Harackiewicz, Rozek, Hulleman, & Hyde, 2012), and theories of intelligence (Blackwell, Trzesniewski & Dweck, 2007). Furthermore, recent research has begun to develop and test instructional interventions based on these theories to address some of the deficits in motivation and achievement mentioned above (Blackwell, Trzesniewski, & Dweck, 2007; Cohen, Garcia, Purdie-Vaughans, Apfel & Brzustoski, 2009; Hulleman & Harackiewicz, 2009).

For example, Blackwell, et al. (2007) found that a classroom intervention that trained middle school students to believe that intelligence is malleable (an incremental theory) produced a more positive trajectory in grades than a program that covered many of the same topics about brain structure but focused on memory rather than the malleability of intelligence. This type of intervention demonstrates the power of developing theory-based psychological interventions for improving motivation and achievement in the classroom. This research is very promising, but much work remains to develop classroom interventions that improve students' motivation and can be implemented by classroom teachers without additional resources. While powerful, interventions like this one are elaborate and difficult to implement under typical instructional conditions. For example, in the Blackwell et al. study (2007), the training was delivered to students in small groups by researchers during advisory periods. In order for teachers to deliver this kind of intervention, they would need to undergo extensive professional development, and would need additional personnel to achieve the student-to-teacher ratio employed in the study.

A second major difficulty in bridging basic research findings to classroom practice has been developing instruction that can be effectively implemented across a number of contexts and populations. Much successful prior work has focused on teaching content or activities that are not covered or easily integrated in the existing curricula (e.g., Blackwell, Trzesniewski, & Dweck, 2007; Cohen, Garcia, Purdie-Vaughans, Apfel & Brzustoski, 2009). For example, Cohen et al. (2009) implemented an effective motivational intervention in which students wrote about positive aspects of their self-concept. However, this activity is not typical to mathematics instruction and teachers may have difficulty incorporating such an activity into a mathematics curriculum, or justifying the use of instructional time for an activity that does not align to the content standards used to guide instruction.

To mitigate these difficulties, researchers need to develop easy-to-implement interventions that can show robust improvement in motivation without large changes to classroom practices. Our goal is to develop a content-general self-assessment activity based on motivational theory that could easily be applied to several academic domains and curricula, and can be administered by teachers with minor alterations. As a first step toward this goal, we tested an instructional intervention designed to affect *multiple* aspects of students' motivation including their achievement goals and interest in science. The intervention consisted of a writing activity called *science diaries* in which students responded to writing prompts at the end of classes. Students in the experimental condition were given prompts to self-assess their competence and interest in science concepts from a given class lesson. We compared this condition to a strong control condition in which students were given prompts to summarize the lesson. We hypothesized that students in the experimental condition would be more likely to adopt mastery goals and increase their interest in the science content than students in the control condition. This intervention is novel in that it is designed to promote two related aspects of student motivation that are known to influence learning, as we will describe next. Moreover, we designed the science diaries in a way that aligns to the instructional objectives in a course, can be flexibly applied in multiple courses without alteration, and do not require additional personnel or expertise from the classroom teacher.

Achievement Goals

Much research has established that learners approach academic tasks with goals that reflect the achievement outcomes they desire. These achievement goals predict both the learning behaviors that individuals employ and the outcomes they achieve (for reviews see Elliot, 1999, and Hulleman, Schweigert, Bodmann, & Harackiewicz, 2010). The dominant approach for describing achievement goals is Andrew Elliot's 2 × 2 theoretical framework that combines goal definition (mastery vs. performance) with valence (approach vs. avoidance) (Elliot & McGregor, 2001). Individuals with mastery goals engage in tasks with the purpose of developing competence and define success with respect to intrapersonal standards of improvement over previous levels of competence (Ames, 1992; Elliot, 1999; Elliot & McGregor, 2001). Individuals with performance goals engage in tasks with the purpose of demonstrating competence defined in comparison to others. With respect to valence, individuals either seek to approach success or avoid failure. Individuals with performance-approach goals aim to demonstrate their competence by outperforming peers. Those espousing performance-avoidance goals aim to avoid demonstrating incompetence by performing no worse than peers. In contrast, individuals with mastery-approach goals seek to improve their level of competence or achieve an absolute standard. Those with mastery-avoidance goals seek to avoid failure by aiming to perform no worse than previous levels of competence.

Each goal has been associated with a particular set of learning behaviors, affect, and cognitions. Learners who have mastery-approach goals tend to employ effective problem-solving practices, expend effort, persist in the face of failure, engage in deep processing, and report greater interest in learning materials (Elliott & Dweck, 1988; Elliot, McGregor & Gable, 1999; Harackiewicz, Barron, Tauer, Carter, & Elliot, 2000; Harackiewicz, Barron, Tauer, & Elliot, 2002; Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008). Learners with performance-approach goals have also been shown to commit high levels of effort (Harackiewicz, et al. 2002) but the learning strategies they employ tend to be more superficial (Elliot, MacGregor, & Gable, 1999). Those who have performance-avoidance goals tend to use surface processing strategies and avoid strategies associated with deep processing (Elliot, McGregor & Gable, 1999). They also demonstrate disorganization and low interest (Elliot & Harackiewicz, 1996; Elliot & Church, 1997). Research on mastery-avoidance is only emerging, but early findings are mixed. Recent research has indicated mastery-avoidance oriented learners employ adaptive strategies like information seeking while avoiding maladaptive strategies (Madjar, Kaplan, &Weinstock, 2011), while other studies find associations between mastery-avoidance goals and more negative outcomes (Van Yperen, Elliot, & Anseel, 2009).

In a review of the literature on achievement goals and achievement outcomes, mastery-approach and performance-approach goals have been found to relate positively to academic achievement as measured by exam performance and course grades (Linnenbrink-Garcia, Tyson & Patall, 2008). However, mastery-approach goals were not found to be associated with achievement outcomes in other analyses (Hulleman, Schweigert, Bodmann, & Harackiewicz, 2010). Students who pursue mastery-approach goals do show evidence of transferring past learning experiences to new tasks (Belenky & Nokes-Malach, 2012, 2013). Performance-avoidance goals have consistently been shown to predict poorer academic performance (Elliot & Church, 1997; Elliot, McGregor, & Gable, 1999; Harackiewicz, Barron, Tauer, & Elliot 2002). In sum, mastery-approach goals have been associated with numerous positive motivational and behavioral outcomes. In this study, we created a writing intervention targeting the promotion of these goals in science; we designed self-assessment prompts that asked students to assess their mastery of recently covered science concepts. In addition to promoting mastery-approach goals, the intervention also contained materials aimed at promoting another type of student motivation: interest in science.

~~We designed self-assessment prompts that asked students to assess their mastery of recently covered science concepts. For example, after a lesson on genetic variation, we prompted students to identify features of a concept they had mastered and another they had not. We hypothesized that by repeatedly prompting students to self-assess mastery, they would increase their awareness of and focus on mastery goals, which~~

~~would lead to higher levels of mastery-goal adoption than students prompted to summarize the class material.~~

Interest

Interest consists of both cognitive and affective components that are activated in response to features of one's environment (Hidi & Harackiewicz, 2000; Renninger, 2000; Renninger, Hidi, & Krapp, 1992; Schiefele, 1991). Most theories of interest hypothesize two types of interest: situational and individual (or personal). *Situational interest* has been described as transient and appears to emerge spontaneously in response to features of the environment (Harackiewicz, et al., 2008); it is associated with both cognitive (e.g., attentional) and affective features (e.g., engagement; Linnenbrink-Garcia, Durik, Conley, Barron, Tauer, Karabenick & Harackiewicz, 2010). It has been observed when environmental stimuli are novel, vivid or intense, and easy to comprehend (Hidi & Harackiewicz, 2000). *Individual interest* is described as dispositional and appears to be long lasting; it is associated with individuals' preferences, increased knowledge, value, and positive feelings for the particular target topic or object (Renninger, 2000).

Hidi and Renninger (2006) describe a four-phase model of interest development. In phase one, some characteristic of a task environment triggers students' interest. In phase two, interest is maintained when those features are perceived as enjoyable or as conferring some type of value to individuals. In phase three, maintained situational interest develops into an emerging individual interest and, in phase four, interests that have emerged become well-developed.

~~To contextualize interest development in science, consider the development of an interest in genetics. Having no prior exposure to the topic, a student's interest may be triggered by a video demonstrating how specific traits of an organism are passed on to~~

descendants through genetic inheritance. If the student begins to perceive knowledge about genetics as having value (perhaps there is concern about passing on a specific trait to a child), interest may be maintained. Alternately, the student may be assigned genetics projects she finds enjoyable, leading to maintained interest. Over time, the student may seek out additional opportunities to study genetics in science classes and may take interest in museum exhibits or television programs about heredity or genetic variation. This repeated exposure gives rise to an emerging individual interest in genetics characterized by increasing expertise and greater curiosity about the topic. As this interest becomes well-developed, the student increasingly values knowledge about the topic, which may give rise to a desire to study genetics as a career aspiration and pursuit of a science major in college.

Research on the relationship between interest and learning outcomes has shown that interest promotes positive learning behaviors (Hidi & Renninger, 2006). Situational interest leads to repeated and prolonged engagement with content (Mitchell, 1993; Renninger & Hidi, 2002). Those with emerging individual interests tend to ask questions and demonstrate effort (Renninger & Hidi, 2002; Renninger & Shumar, 2002). Those with well-developed individual interests do all these things and also demonstrate self-regulation and deep strategy use, as well as more frequent consideration of content and context in problem-solving scenarios (Lipstein & Renninger, 2006). With respect to achievement outcomes, interest has been shown to positively affect students' course grades (Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008).

In this study, we designed a series of prompts that focus students on instances when their interests were triggered and maintained. Additional prompts elicit students' reflections on their well-developed and emerging interests and the relationship between those interests and science lessons. We also prompt students to engage in effortful self-assessment and generation of questions. These actions are characteristic of students who already exhibit interest, and such prompts should support interest development (Renninger & Shumar, 2002). Together, these distinct types of prompts should elicit multiple components of situational interest, and should operate in conjunction with prompts designed to promote mastery-approach achievement goals ~~For example, the following prompt was meant to elicit an identification of situational interest, an exploration of why the topic was interesting, and an acknowledgement of how students responded to something that triggered their interest: "*Think of something that was interesting in today's lesson. Did you try to understand the idea better? Did you write it down so you would remember it? Did you ask questions? Describe how you respond to interesting ideas.*" The individual interest prompts were designed to encourage students to connect science to their emerging or developed interests. The prompt, "*Name one of your interests outside of class. How can it be studied scientifically?*" draws on an individual interest and encourages the student to relate it to science. Prior work has shown that students sometimes do not consider science-related activities as science because they categorize them as other types of activity (Basu & Barton, 2007). By having to explicitly connect an individual interest to science, the students have an opportunity to re-categorize that previous interest or aspects of that interest as being related to science (Ohlsson, 2009).~~

Relationship Between Achievement Goals And Interest

Motivation theorists postulate that interests are strongly related to achievement goals (e.g., Hidi & Harackiewicz, 2000), and a reciprocal relationship between mastery goals and interest has been repeatedly demonstrated through empirical study (Harackiewicz, Barron, Pintrich, Elliot & Thrash, 2002; Harackiewicz, Barron, Tauer,

& Elliot, 2002; Harackiewicz, Durik, Barron, et al., 2008; Hulleman, Durik, Schweigert, & Harackiewicz, 2008). For example, Harackiewicz and colleagues (Harackiewicz, Durik, Barron, et al., 2008) found that interest and mastery goals predicted one another, and that both influenced achievement. Results of a path model indicated that initial individual interest promoted mastery goal adoption, which in turn predicted both triggered and maintained interest. Students' triggered situational interest was found to predict triggered interest in future course activities, as well as final grades in a course. Both mastery goals and interest have been shown to positively affect learning behaviors and outcomes, and each construct reinforces at least one component of the other. When combined, the effects on behavior and outcomes may be additive or even interactive; thus, interleaving prompts that target one and then the other construct may be more effective than either set of prompts alone.

Writing To Improve Achievement Goals And Interest

We aim to promote mastery goal adoption and interest in science through writing. In recent years, interventions involving brief writing tasks have been shown to diminish the negative effects of psychological variables like test anxiety (Ramirez & Beilock, 2011) and stereotype threat (e.g., Cohen et al., 2006). More extensive writing interventions have been shown to help individuals ameliorate negative psychological effects of trauma (Smyth, 1998) and buffer against maladaptive rumination (Sloan, Marx, Epstein & Dobbs, 2008).

For example, Cohen and colleagues (2006) tested whether a writing intervention could buffer the potential effect of stereotype threat on an individual who is predicted to perform poorly on an assessment based upon demographic characteristics. In their studies, students of minority status were asked to write self-affirming reflections, focusing on a valued relationship, interest, or ability. These interventions reduced psychological threat and stress and led to improved grade point averages, effectively reducing the achievement gap.

In addition to a strong record of facilitating motivational change in prior research, writing interventions also help students develop some of the academic skills that schools aim to impart to their students. In this study, the activities required by both the control and experimental writing tasks supported the school's goal to incorporate more writing assignments into classes. The task also aligned to new standards for science education that stress writing as an essential practice in science (Next Generation Science Standards, 2013; e.g., Practice 8, Obtaining, Evaluating, and Communicating Information).

In line with prior research that obtained large effects on motivational variables using brief writing interventions, we tested whether these effects can be achieved for mastery goals and interest. While it has been repeatedly shown that writing interventions can induce large effects on motivation and achievement, it is often unclear exactly how these interventions work, and what mechanisms give rise to the effects. Next, we explain how prompting students to self-assess interest and understanding through writing could influence mastery goals, interest in science, and science achievement. In particular, we focus on three different possible mechanisms: goal creation, articulation, and feature focusing.

Goal creation and articulation

The prompts may facilitate mastery goal creation by making the concept of mastery explicit as a viable and important goal for learning. The instruction students typically receive includes an implicit goal to learn the material presented, but rarely are rubrics provided for self-assessing whether or not one has learned the target concept or skill. Consider the following prompt: "*Think of a concept that you feel like you kind of* *understand, but haven't mastered. What do you feel like you know for sure? What parts do you need to learn more about? How will you master these parts?*" Mastery prompts like these urge students to develop explicit intrapersonal criteria for what it means to master something. Furthermore, by articulating their level of competence and generating specific plans for learning a yet-to-be-mastered concept or skill, students may not only explicitly adopt these goals but also may be more likely to pursue them (Gollwitzer, 1999). Articulating one's goal may also have implications for students' recognition of their interests. When students describe a learning goal, they may see it as an opportunity to engage with a topic they are intrigued by and want to learn about. In this sense, articulating a mastery goal may also trigger students' interest.

Feature focusing

Another way in which the writing prompts may produce changes in the students is by helping students gain an awareness of their own motivations, and how they can understand them. That is, when students make self-assessments of mastery, they spend a considerable amount of time focusing on the *features* of mastery for particular concepts and skills. Through repeated self-assessment practice, students may begin to learn the features they associate with mastery and thereby have new criteria to help them assess their own understanding. Prompts such as "*How do you know you understand?*" encourage students to reflect on the features of mastery. Such questions require students to set a criterion against which they evaluate their mastery of a concept. For example, through repeated self-assessment a student may come to learn that an important feature of mastery is the ability to explain. Repeated self-assessment offers an opportunity to reflect on patterns observed in those criteria. Furthermore, questions like "*What do you not understand?*" and "*How do you know you do not understand?*" give students opportunities to compare and contrast mastered and yet-to-be-mastered concepts, and to identify features of their knowledge of concepts they believe they do or do not understand. Paying attention to the features of mastery could lead to a better understanding of what it takes to master something. It could also lead to more accurate self-assessment, which could improve subsequent learning. For example, if a student better understands when something is not mastered then he or she can engage in activities to acquire the desired mastery.

~~Similarly, questions that prompt self-assessment of interest focus respondents on multiple features of interest. Some of the prompts focus them on times when their interests were triggered such as "*If you wanted to get someone interested in today's topic, how would you do it?*" and others focus on questioning practices associated with maintaining and developing interest, such as "*Are there questions you'd like to ask tomorrow about today's science lesson? Are there things you'd like to know more about?*" Others may help students identify emerging interests like "*If you could ask your teacher to tell you more about one thing from today's lesson, what would it be? Why?*" Knowledge of these features could help a student better identify when she is interested in an idea or activity and thereby increase engagement. Additional prompts like "*Name one of your interests outside of class. How can it be studied scientifically?*" provide students opportunities to relate personal interests outside the class to topics covered in science class. The act of elaborating on connections between outside interests and science content can increase students' awareness of the relevance of science content to their own lives and have a positive influence on students' interest in science (Hulleman & Harackiewicz, 2009). In sum, the variety of interest prompts we incorporate can cue students to focus on features of both situational and individual interest, the development of interest, and the behaviors characteristic of individuals who possess each type of interest.~~ We expect goal creation and articulation as well as feature focusing to affect students' self-reported endorsement of mastery goals and interest in science at posttest. Responding to prompts can help make mastery goals and interests explicit and help students learn the features of mastery and interest to better identify their presence and absence. They can also help students articulate a plan for acquiring mastery and bridging personal interest to situational interest.

~~We believe the prompts will work through these mechanisms, for the reasons just described.~~ If the prompts successfully affect mastery goals and interest, we will conduct future studies to examine whether goal articulation, creation, or feature focusing are responsible for the effects. For now, however, we are focused on testing whether prompting will induce stronger mastery goals and situational interest. Mastery prompts were designed specifically to focus on students' definition of mastery and had no explicit approach/avoidance valence. As a result, we suspect that prompts may affect both mastery-approach and mastery-avoidance goals.

A focus on middle school science

We targeted our intervention for middle school because interest and achievement in science are known to diminish in this period (Osborne, Simon, & Tytler, 2009). Evidence from multiple international studies indicates that interest in science is robust at age 10, but declines considerably by age 15 (Haworth, Dale, & Plomin, 2008; Jenkins & Nelson, 2005; Lyons, 2006; Murphy & Beggs, 2005; Osborne & Collins, 2001; Pell & Jarvis, 2001). Early adolescence appears to be a sensitive period for promoting the importance of science. Young adolescents are more likely to graduate from college with a science degree if they expect to pursue a career in science, and early promotion of science interest is key to developing science aspirations (Tai, Liu, Maltese & Fan, 2006). These findings suggest middle school is an important time period to arrest these declines in motivation to learn science. Since goals and interest are known to decline in this age group, one particularly interesting possibility will be to see if the degree to which increases in students' situational interest actually *predicts* long-term individual interest.

Hypotheses

The overarching goal of this study was to test whether a classroom intervention that is easy for a teacher to implement and adheres to classroom learning objectives can increase middle school students' motivation in science classes. We tested the following hypotheses:

(1) At posttest, students in the experimental condition will report stronger mastery-approach and mastery-avoidance goals.

(2) At posttest, students in the experimental condition will show more interest in science topics than students in the control condition.

(3) Increases in situational interest in science lessons will predict higher levels of individual interest in science as a domain.

Methods

Participants

Participants were students enrolled in two classes of life science (seventh grade) taught by one teacher and two classes of physics (eighth grade) courses taught by another teacher at an urban middle school with an explicit focus on science and technology. Teachers had previously worked with the research team on prior studies. One hundred and one students were initially recruited from these courses. The final sample included 53 students.

While 97% of students in the sample completed the school year and received fourth-quarter grades, a high percentage of absences during the final weeks of the semester led to a considerable amount of missing data for posttest measures of motivation. We obtained a complete set of data for 53 students (26 experimental, 27 control; 23 seventh graders, 30 eighth graders). We conducted a series of analyses to investigate whether the number of students who were absent systematically differed across the two randomly assigned conditions. We also examined whether those who were absent for the posttests differed from those who were present on measures of academic achievement and key demographic variables across conditions.

We conducted a Chi-square test to determine whether the two diary conditions were differentially affected by the absences at posttest. The Chi-square test revealed no differences, χ^2 [1, 101] = .09, *ns*, showing that both conditions were equally affected by the absences. There were equal proportions of absences across the experimental (49% of students absent) and control condition (46%), which is consistent with what would be expected since the students were randomly assigned to condition.

Next we conducted a 2 (condition: experimental vs. control) by 2 (attendance: present vs. absent) analysis of variance (ANOVA) to determine whether those who were absent had different levels of prior academic achievement than those who were present. Prior academic achievement was assessed by students' second-quarter grades for science content, which were recorded before our intervention took place. Student grades could range from 1 (low achievement, i.e., an F) to 5 (high achievement, i.e., an A). The ANOVA revealed an effect of attendance on grades, F (1, 100) = 15.95, MSe = 1.20, p = .001 d = .80, indicating that students who were absent differed from those who were present on their second-quarter grades. Students who were absent (M = 2.88, SD = 1.21) scored nearly a full point (i.e., one letter grade) lower than those who completed the posttest ($M = 3.75$, $SD = .95$). Importantly, there was no effect of condition and no interaction of condition by attendance, Fs < 1. This shows that although the students who were absent were more likely to be those who had lower achievement compared to those who completed the posttest, this relationship did not differ by condition. Those who were present across the two conditions had similar levels of prior achievement.

Because the two diary conditions did not differ in overall attendance or prior achievement, we focus on only those participants who completed all of the posttest measures ($N = 53$). This sample of 53 students was 44% female and included students who self-identified as African American (45%), Caucasian (45%), Hispanic (4%), Asian (2%), and mixed ethnicities (2%), with 2% declining to report. A substantial portion of students received free (48%) or reduced-price (7%) school lunches, indicating lower socioeconomic status. Thirty percent of the students were designated as gifted, while 9% had other special education designations stemming from disabilities (i.e., individualized education programs, IEPs). These data show that this sample retains important variation in gender, ethnicity, SES, and IEP status that is representative of the larger school population.

To make sure the students did not differ across diary conditions on these key demographic variables, we conducted a series of Chi-square tests. These tests revealed no differences between the experimental and control conditions for gender (χ^2 [1, 53] = .46, *ns*), ethnicity (χ^2 [5, 47] = 5.08, *ns*), SES (χ^2 [2, 44] = 1.56, *ns*), IEP status (χ^2 [5, 43] = 1.21, *ns*), or grade level (χ^2 [1, 53] = .03, *ns*). We therefore have evidence that the two conditions were similar on all demographic variables.

Materials

Students completed questionnaires measuring their achievement goals for and interest in science at the beginning and end of the spring term. During the term, they completed a series of writing prompts we refer to as a *science diary*.

Achievement goals

We used the Achievement Goals Questionnaire - Revised to measure learners' achievement goals (Elliot & Murayama, 2008). This 12-item scale distinguishes between mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance goals using three items to assess each goal. For each item, students rate their endorsement of the item statement from 1 (strongly disagree) to 6 (strongly agree). Descriptive statistics and reliability coefficients measuring internal consistency of scales appear in Table 1.

Science interest

Students completed measures assessing situational and individual interest. The situational interest scale was composed of twelve items that used a Likert scale ranging from 1 (not at all true) to 5 (very true) (Linnenbrink-Garcia, Durik, Conley, Barron, Tauer, Karabenick, et al., 2010). Three 4-item subscales assessed the degree to which situational interest was triggered by science lessons, maintained through perception of their value, or maintained through enjoyment. For the purposes of this study, we were interested in situational interest as a unitary construct and measured it by taking the mean across all items. Students also completed an individual interest scale composed of eight items that employed the same Likert scale as the situational interest scale (Linnenbrink-Garcia, et al., 2010). Both scales were designed to assess middle school students' interest in mathematics; we adapted the instruments for science. Descriptive and reliability statistics appear in Table 1. Six subjects did not complete all interest measures, decreasing the sample size for these hypotheses to N=47.

Science diaries

Students were randomly assigned to the experimental (mastery and interest prompts) or the control diary condition (summary prompts) and teachers were blind to this assignment. In the experimental condition, students were prompted to self-assess the degree to which they mastered the science knowledge presented during a lesson as well as the degree to which the lesson was interesting to them. In contrast, students in the control condition responded to prompts that directed them to summarize the knowledge that was covered in that class session. Rehearsal and retrieval practices involved in summarization are known to promote content learning (Karpicke & Roediger, 2007; King, 1992), but are not known to affect motivation.

In order to ensure that the teachers could successfully deliver the intervention in their classes, we worked with the teachers to design the study materials. We drafted the diary prompts over several iterative cycles with teacher feedback on the appropriateness of the language and the format of presentation to the students. The results of this collaboration were two sets of twenty prompts contained in binders that students kept in the classroom. We worked with the teachers to incorporate diary sessions into their courses 2-3 times per week, and provided them with scripts to introduce the project to students, to initiate a diary session, and to provide students with instruction about how to complete entries (i.e. "Complete the next blank entry, even if the one you are completing doesn't seem to be the same one as your classmates"). List of all prompts presented to each group appear as Appendices A and B.

We made the two science diaries as similar as possible (i.e., both tasks required writing for the same length of time) in order to minimize the risk that students would notice their classmates were completing a different type of classroom activity, which could potentially compromise the intervention and students' reactions to it. We chose to have all students engage in a writing activity so that the teacher could give the *entire* class the same general rationale for the activity and incorporate it as a part of the curriculum. The prompts were designed so that they could be flexibly applied across multiple science curricula. In the seventh grade course, students studied a life science curriculum covering topics such as food webs, population change, genetic variation, and heredity. In the eighth grade course, students studied a physics curriculum and covered topics including the properties of waves, matter, and electricity. The teachers had been teaching middle school science for six (seventh grade teacher) and seven years (eighth grade teacher).

Procedure

At the beginning of the second semester, students were asked to complete a questionnaire during class. The questionnaire was administered by their teacher and was described as a brief survey concerning their opinions about science and learning. Later that week, teachers introduced the "Science Diary Project," explaining that students would receive a binder of prompts to stimulate reflection and writing about science lessons. Once or twice a week, students were instructed to open to the first blank prompt and write for the full 10 minutes allotted. Students completed a substantial number of diary entries, though the number of entries completed varied as a result of attendance. On average, students completed 10 prompts over the course of the semester (Experimental M = 9.92, SD = 3.33, Control M = 10.67, SD = 3.06). Their entries were typically between two and six sentences long (Experimental M = 3.59, SD = 1.51; Control M = 3.73, SD =1.21). The number and length of entries completed were not significantly different between groups, Fs < 1. At the end of the semester, students completed an identical questionnaire assessing achievement goals and interest in science.

Results

Achievement goals

We hypothesized that students in the experimental condition would report stronger endorsement of mastery-approach and mastery-avoidance goals than students in the control condition. To test this hypothesis we conducted separate one-way analyses of covariance (ANCOVAs) to assess all four achievement goals at posttest using respective pretest scores as covariates. Figure 1 shows the adjusted mean posttest scores for the two conditions on each achievement goal after controlling for their pretest scores.

For mastery-approach goals, the analysis revealed a large effect for the covariate, F (1, 53) = 84.15, MSe = 0.62, $p < .001$, $d = 2.61$, showing that students' pretest mastery-approach scores predicted their posttest mastery-approach scores. The analysis also revealed a medium effect of the intervention on mastery-approach goals, F (1, 53) = 5.50, MSe = 0.62, $p = .023$, $d = .44$. This shows that students in the experimental condition had higher mastery-approach scores at posttest than students in the control condition after controlling for their pretest scores. A similar pattern of results was found for mastery-avoidance goals. There was an effect of the covariate, F (1, 53) = 8.30, MSe = 1.58, $p = .01$, $d = .80$, showing that the pretest mastery-avoidance scores predicted post-test mastery-avoidance scores. Analyses also revealed a medium effect of the intervention on posttest mastery-avoidance scores, F (1, 53) = 4.15, MSe = 1.58, $p = .05$, $d = .40$. These results confirm Hypothesis 1; students in the experimental condition were more concerned with developing their understanding and learning of science than the students in the control group. Although we were not specifically targeting mastery-avoidance goals, our intervention shows that students in the experimental condition were also more concerned than the control group with not losing prior mastery and understanding of science concepts.

Analyses revealed a large effect of the covariate for performance-approach goals, F (1, 53) = 33.50, MSe = 1.24, p < .001, d = 1.63, showing that students' pretest performance predicted posttest performance. However, there was no effect of the intervention, F (1, 53) = .94, *ns*, showing that the two conditions did not differ in their performance-approach scores at posttest. This same pattern of results was found for performance-avoidance goals. Pretest performance-avoidance scores predicted posttest scores, F (1, 53) = 13.72, MSe = 1.53, p < .001, d = 1.06, but there was no effect of the intervention, F (1, 53) = 2.61, *ns*. In sum, these results indicated that the science diary intervention successfully affected students' adoption of both types of mastery goals when learning science without affecting students' adoption of performance goals.

Interest in science

For the composite situational interest scale, students' scores were calculated by averaging across twelve items (scaled 1 to 5) with higher scores indicating higher amounts of interest in science lessons. Individual interest scores were scaled identically using eight items assessing interest in science as a domain. Figure 2 shows the adjusted mean posttest scores for the two conditions on each interest scale after controlling for their pretest scores.

We hypothesized that students in the experimental condition would report significantly greater situational interest at posttest than students in the control condition. The analysis revealed a large effect for the covariate, F (1, 52) = 6.05, MSe = .39, p < .001, d = 1.71. Students' pretest situational interest scores predicted their posttest situational interest scores. There was also a medium effect of diary condition on students' situational interest in science, F (1, 52) = 6.05, MSe = .39, p =.02, d = .68. These results are consistent with our hypothesis that the students in the experimental condition would find science lessons more enjoyable and valuable than the students in the control condition.

With respect to individual interest scores, results of an ANCOVA revealed a large effect for the covariate, F (1, 52) = 39.36, MSe = .53, $p < .001$, d = 1.25, indicating that pretest individual interest scores predicted posttest levels of individual interest in science. However, there was no effect of diary condition on posttest for individual interest when controlling for pretest scores, F (1, 52) = .98, *ns*. In sum, the intervention successfully affected situational interest in science lessons, but it did not have a significant effect on individual interest in science as a domain.

Situational interest and individual interest in science

Hidi and Renninger (2006) theorized that students who maintain situational interest tend to repeatedly engage in content, spurring emergence and strengthening of individual interest until it is well developed. Accordingly, we hypothesized that increases in situational interest in science might predict higher levels of individual interest in science as a domain at posttest. A single predictor regression analysis indicated that increased situational interest (posttest score minus pretest score) predicted individual interest at posttest, F (1, 52) = 9.12, p =.004, β = .38, R^2 = .15.

Discussion

Consistent with the predictions made in Hypothesis 1, students in the experimental condition reported higher mastery-approach and mastery-avoidance goal scores than students in the control condition at posttest. Students in the experimental condition also reported higher levels of situational interest than students in the control condition at posttest (Hypothesis 2). While the intervention affected situational interest in science topics, it did not affect students' individual interest in science. It is likely that the intervention was too brief to have had an effect on individual interest, which is consistent with Hidi and Renninger's (2006) theory that students first need to trigger and maintain situational interest before developing individual interest. Also consistent with Hidi and Renninger's (2006) model of interest development; increases in situational interest had a positive relationship to individual interest (Hypothesis 3). However, we cannot say whether this finding indicates that increasing situational interest predicts higher individual interest or whether those high in individual interest are more apt to increase in situational interest when prompted to reflect on their interest in science topics.

In sum, these results confirm that the instructional intervention was successful in simultaneously promoting two related motivational constructs: mastery goals and situational interest. The ability to affect multiple related aspects of students' motivation in science class through a classroom intervention is a novel finding that has important implications for both theory and instructional practice.

Implications for Theories of Motivation and Instruction

Prompting students to self-assess their understanding and interest in science was an effective method of influencing middle school students' science motivation. The experimental condition of our science diary successfully affected two different motivational constructs. This demonstrates that multiple motivational constructs can be addressed simultaneously. Importantly, we chose these two constructs because prior motivational theory suggests they are related. Had we chosen two unrelated constructs, it is possible that we would have found no effects because, targeted separately, the intervention may have been too weak. Our approach required careful consideration of the features of instruction and how they map onto the motivational constructs of achievement goals and various levels of interest. In order to manipulate multi-faceted theoretical constructs in applied contexts, it is essential to use theory as a guide when selecting features of the instructional materials. In prior research, initial interest has been shown to predict mastery-approach goals, which in turn predict further interest (Harackiewicz, et al. 2008). Based on this mutually reinforcing relationship, the instructional intervention was designed to target multiple features of both interest and mastery-approach goals. As a result, the experimental condition of our diary intervention successfully increased students' mastery goal adoption and their situational interest in science lessons.

Instructional interventions based on motivational theories can be powerful. Their effectiveness in this and prior studies suggests that they hold promise for influencing students' ability to engage in instructional activities, predicting improved performances in those activities, and preparing students for future learning. Choosing multi-faceted constructs is a good first step to develop a powerful intervention that builds on the theoretical relationships between different aspects of motivation. Although we were able to promote two aspects of student motivation in science with a brief, written self-assessment, we cannot say exactly which mechanisms underlie the effects. Below we speculate on five possibilities: making mastery goals and interests explicit, learning the features of mastery and interest to better identify their presence and absence, articulating a plan for acquiring them, bridging personal interest to situational interest, and prompting metacognitive monitoring.

Mastery prompts required students to attend to features of a mastery goal. Students identified content they had and had not mastered, and explained the criteria they used to define mastery. Across prompts, students were repeatedly primed to focus on numerous features of mastery, which could have led them to explicitly create learning goals and learn the features associated with having and attaining mastery. The prompts also required students to formally articulate a learning goal in order to self-assess their attainment of that goal. This goal articulation process may have increased the likelihood that students adopted mastery goals and pursued them. This activity of writing out the specifics of how to accomplish a goal is similar to Gollwitzer's (1999) "implementation intentions," in which students who wrote out a specific plan for accomplishing a goal were more likely to adopt and pursue that goal.

Interest prompts focused students on various aspects of interest within Hidi and Renninger's (2006) four-phase model. Students were asked to identify elements of science lessons that triggered and maintained their interest and, in other prompts, to identify instances where they possessed well-developed or emerging individual interests in a particular topic. Collectively, these prompts focused students on features of interest and required them to articulate their interests in the domain. The combination of articulating these interests and considering what they might do to revisit or more deeply engage these science topics in or out of class may have prompted deeper consideration of science concepts. Interest prompts also asked students to name individual interests unrelated to science and to consider how they could be studied scientifically or connected to science concepts. These may have prompted students to consider scientific dimensions of their individual interests, helping students to redefine a personal interest as a science-related interest. Finally, many of the prompts asked students to come up with questions they would ask a peer, teacher, or expert in order to learn more about a science topic. These prompts scaffolded students' curiosity, an attribute Hidi and Renninger (2006) associate with later stages of interest. It is possible that scaffolding this behavior may have increased students' interests in the concepts they covered and then reflected upon in the diary.

Because both sets of prompts asked students to reflect upon prior learning, they effectively prompted metacognitive monitoring and evaluation (Flavell, 1979). Students in the control group were prompted to reflect on what they had learned about a topic, and to rehearse it by summarizing. In the experimental group, the mastery prompts also asked students to reflect on what they had learned, but the prompts explicitly framed students' reflections in terms of mastery-oriented features. This framing may explain why mastery goals were more strongly adopted in this condition. Similarly, by prompting students to draw connections between the class content and interests, we may have increased their tendency to find science topics interesting. While students in the control group focused solely on rehearsing what they had learned, students in the experimental group spent time reflecting not on what they learned, but how well they learned the lessons and concepts and whether they found them interesting.

Limitations

When interpreting the findings obtained in this study, it is important to be aware of the limitations associated with the experimental context, approach, and measures. The study was conducted with a sample of students in a middle school with a focus on science and technology. One should be cautious generalizing these findings to students of other ages and in different learning domains or classroom contexts.

The attrition that occurred in this study also limits the generalizability of the findings with respect to learners of a similar age and context. We documented that low achieving students were underrepresented in the sample, thus the effects of the intervention on this population are unclear. There may also be other differences between those who completed the study and those who did not. This attrition also limited the power available to detect effects of our intervention. Our intervention was relatively brief, and students' engagement in the activity was limited. Students wrote only a small number of diary entries, and entries contained only a couple of sentences each. This limited amount of effort produced promising outcomes, but we cannot say whether a more intensive intervention of this type would produce proportionally larger effects. Because we randomly assigned students to conditions within classrooms, we conferred with teachers weekly to monitor whether students were aware of and affected by differences in daily prompts. Students voiced no awareness that prompts differed due to condition. Finally, our measurement approach relied exclusively on self-report questionnaires as measures of achievement goals and interest. Because the intervention materials repeatedly incorporate vocabulary associated with mastery and interest, there is some overlap with the language employed by the motivational assessment tools used in the study. Because the language is similar, it is possible that the intervention induced a demand effect where learners tend to endorse items more strongly when they contain familiar terms. If this is the case, the intervention may have affected their responses without actually affecting their underlying motivation. However, we believe that a demand effect is unlikely. If a demand effect was present we might expect the experimental group to demonstrate increases in scores induced by demands placed by the intervention materials, while the control group should evidence little change. However, the current data indicate that the experimental group showed some increase in both mastery goals and interest, while the control group showed a *decrease* in motivational measures. If our results were due to a strong demand effect, we would see a different set of changes than those we observed. In the future, it would be useful to develop some type of behavioral measures of these constructs to avoid some of the measurement issues associated with self-report methods.

Conclusion

These findings demonstrate the power that simple writing interventions can have on educational outcomes when they are designed to support curricular objectives and are instantiated by teachers as part of standard classroom practices. A classroom activity requiring ten minutes of instructional time and completed roughly once a week over the course of a semester had the effect of significantly altering students' motivation. Summing the ten-minute exercises that occurred weekly during an 18-week semester, an instructional practice requiring just three hours out of a semester of instruction was sufficient to achieve these effects on motivation in science classes. Prompting self-assessment costs little and appears to be a useful classroom exercise that promotes students' desire to master science concepts and enables them to make connections between science lessons and their personal lives.

These findings add to an emerging research base demonstrating that writing interventions targeting students' motivation can successfully affect specific motivational constructs. Prior work by Aronson, Fried, and Good (2002) demonstrated that writing interventions can relieve anxiety and increase performance for students typically influenced by stereotype threat. Hulleman and Harackiewicz (2009) demonstrated that having students write about the relevance of science content can influence the motivation and performance of low-achieving high school students. Additional studies demonstrate that writing interventions inducing motivational change can have benefits that persist for years (e.g. Cohen et al., 2009). Based on our findings and this body of evidence, incorporating writing exercises that target motivational constructs into standard classroom practice should be encouraged in order to help students develop a motivational profile that is associated with positive learning outcomes.

Improving students' motivation to learn is important at any age, but the ability to do so in a time period characterized by precipitous declines in interest and achievement is critical. If writing interventions that target motivational constructs can be instantiated into the curriculum across middle and high school science classes, it is likely that these exercises may limit or even reverse the declines that have been documented in student interest and achievement in science.

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Appendix A

Experimental Group Prompts

1. [m] Name one thing that you understood well from today's lesson. How do you know that you understand it? How would you show someone you understand it?
2. [i] Name one concept or idea you learned today that you found interesting and explain why it was interesting.
3. [m] Name something from class this week that you feel like you mastered. Explain it using your science vocabulary.
4. [i] Are there questions you'd like to ask tomorrow about today's science lesson? Are there things you'd like to know more about?
5. [m] Name one concept or topic that you had difficulty understanding in today's class. Why was it challenging? If you understood everything, what might someone else find difficult and why?
6. [m] Name a concept you have learned recently that will be helpful for learning about science in the future? How will it help?
7. [i] If you wanted to get someone interested in today's topic, how would you do it? Give an example or two.
8. [m] Think of a concept you've covered in this science topic that you understand completely. Name it and explain it.
9. [i] What is something that you've covered in science that you know is important, but you didn't find interesting. What could have been done to make it more interesting?
10. [i] What concept have you learned recently that will be helpful outside of class? How will it help?
11. [i] Name one recent topic from science class that you find interesting but don't know a lot about. What's interesting about it? What do you want to learn about it?
12. [m] Think of a concept that you feel like you kind of understand but haven't mastered. What do you feel like you know for sure? What parts do you need to learn more about? How will you master these parts?
13. [i] If you could ask your teacher to tell you more about one thing from today's lesson, what would it be? Why?
14. [m] If you had to explain today's lesson to a friend, how well do you think you could explain it? What would you have trouble explaining? What could you explain really well?
15. [i] Name one of your interests outside of class. How can it be studied scientifically?
16. [m] If you could learn more from an expert scientist about anything you learned today, what would you choose? Why?
17. [m] What did you find difficult to understand from today's lesson? What about it was difficult?
18. [m] How well do you feel like you understand the day's lesson? What part did you understand? What part presented a challenge?
19. [i] Think of something that was interesting in today's lesson. Did you try to understand the idea better? Did you write it down so you would remember it? Did you ask questions? Describe how you respond to interesting ideas.
20. [m] Name one thing from this week's lessons that you found difficult to understand. How do you know you didn't understand it well? What would you do to improve your understanding?

[m] –prompt targeting mastery goals [i] – prompt targeting interest

Appendix B

Control Group Prompts

1. Name the three most important ideas from today's class. Write a few sentences to help you remember each.
2. You have been hired to act as a spy for a science teacher from another school who will teach the same lesson next week. Provide a report of what happened in class today you can give to her.
3. Write a set of matching questions using material from today's lesson. (Example: match the definition to the vocabulary word)
4. Try to summarize today's lesson in one paragraph.
5. What from today's class would you study for a test? Make a few notes.
6. What was the take-home message from today's class?
7. Friday only - Name the three most important concepts from this week. Define them.
8. If an adult at home asked you what did in science class today, what would you tell them?
9. Summarize today's class in a brief paragraph as if you were providing a brief news story to be published in a school paper.
10. Describe three concepts from today's class.
11. Summarize today's science lesson in 5-7 sentences.
12. Make an outline of today's science lesson.
13. Pretend your friend was absent from class. What are two things from today's class you would tell him/her to help them study for the test?
14. Write two fill in the blank questions using material from today's science lesson. Example: Ice melts at _____ degrees Fahrenheit.
15. Pick one idea from today and write a paragraph describing it so that it is useful to you on the test.
16. If you could write a summary of today's lesson to use on your next test, what would you write?
17. Describe one thing you learned in today's lesson. Give as many details as you can.
18. Make a study guide for today's science lesson.
19. Pretend your friend was absent from class today. Please explain to them what you did in class today. Be as specific as you can.
20. Write a list of vocabulary words from today's lesson. Define them.

Table 1
Descriptive Statistics and Reliability Scores

	Experimental (*n* = 26)		Control (*n* = 27)		Total (*N* = 53)		
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*α*
Pretest mastery-approach goal score	4.74	1.12	4.60	1.04	4.67	1.07	0.83
Posttest mastery-approach goal score	4.92	1.26	4.29	1.30	4.60	1.31	0.93
Pretest mastery-avoidance goal score	4.47	1.30	4.06	1.23	4.27	1.27	0.65
Posttest mastery-avoidance goal score	4.97	1.28	4.09	1.40	4.52	1.40	0.93
Pretest performance-approach goal score	4.88	1.02	4.45	1.30	4.66	1.18	0.77
Posttest performance-approach goal score	4.79	1.52	4.16	1.33	4.47	1.45	0.91
Pretest performance-avoidance goal score	5.27	0.74	4.19	1.60	4.71	1.36	0.71
Posttest performance-avoidance goal score	5.00	1.37	3.85	1.39	4.41	1.49	0.92
Pretest situational interest score	3.37	0.73	3.34	0.66	3.36	0.69	0.90
Posttest situational interest score	3.49	0.87	3.01	0.77	3.24	0.85	0.92
Pretest individual interest score	3.88	0.81	3.80	0.77	3.84	0.79	0.92
Posttest individual interest score	3.64	0.95	3.42	0.98	3.53	0.96	0.92

Table 2

Bivariate correlations among major study variables

	Measure	1	2	3	4	5	6	7	8	9	10	11	12
1	Pretest mastery-approach goal score	--	.38*	.74*	.37*	.63*	.56*	.78*	.40*	.71*	.52*	.52*	.58*
2	Pretest mastery-avoidance goal score		--	.36*	.58*	.38*	.28*	.32	.41*	.19	.23	.23	.35
3	Pretest performance-approach goal score			--	.47*	.62*	.48*	.72*	.46*	.65*	.53*	.53*	.57*
4	Pretest performance-avoidance goal score				--	.23	.21	.36*	.43*	.37*	.55*	.22	.26
5	Pretest situational interest score					--	.73*	.54*	.30	.55*	.45*	.57*	.54*
6	Pretest individual interest score						--	.53*	.32*	.69*	.55*	.68*	.69*
7	Posttest mastery-approach goal score							--	.63*	.76*	.60*	.66*	.70*
8	Posttest mastery-avoidance goal score								--	.46*	.61*	.55*	.48*
9	Posttest performance-approach goal score									--	.77*	.61*	.67*
10	Posttest performance-avoidance goal score										--	.52*	.57*
11	Posttest situational interest score											--	.81*
12	Posttest individual interest score												--

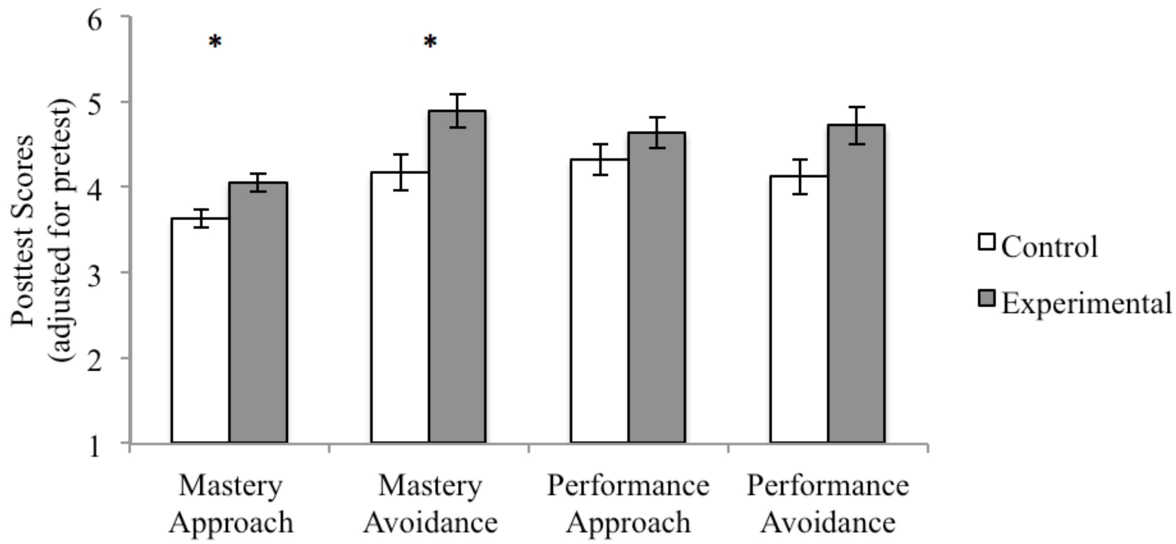

Figure 1. Adjusted mean posttest scores and standard errors on measures of achievement goals.

Note. * - $p < .05$

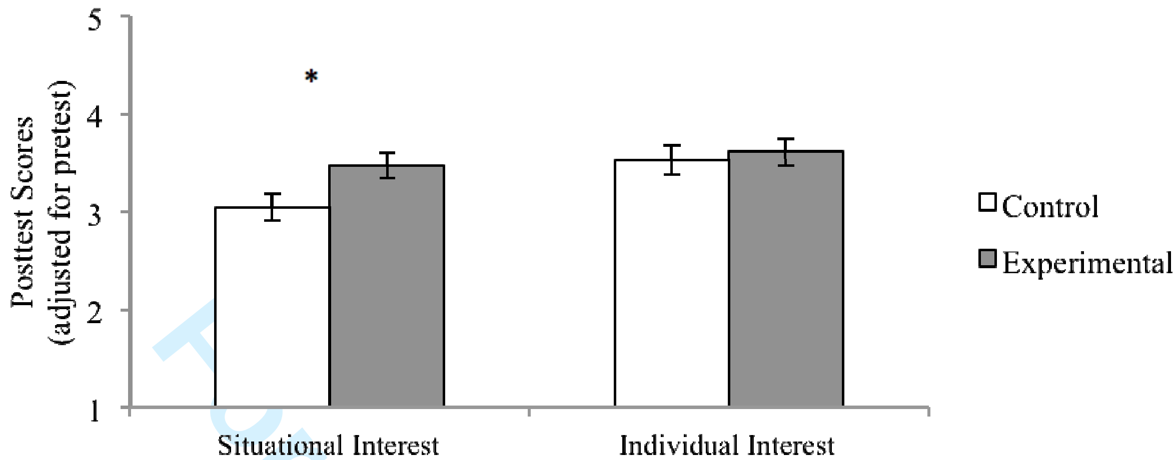

Figure 2. Adjusted mean posttest score and standard errors on measures of interest.

Note. * - $p < .05$