To master or perform? Exploring relations between achievement goals and conceptual change learning

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Background. Research is needed to explore conceptual change in relation to achievement goal orientations and depth of processing.

Aims. To address this need, we examined relations between achievement goals, use of deep versus shallow processing strategies, and conceptual change learning using a think-aloud protocol.

Sample and Method. Seventy-three undergraduate students were assessed on their prior knowledge and misconceptions about Newtonian mechanics, and then reported their achievement goals and participated in think-aloud protocols while reading Newtonian physics texts.

Results. A mastery-approach goal orientation positively predicted deep processing strategies, shallow processing strategies, and conceptual change. In contrast, a performance-approach goal orientation did not predict either of the processing strategies, but negatively predicted conceptual change. A performance-avoidance goal orientation negatively predicted deep processing strategies and conceptual change. Moreover, deep and shallow processing strategies positively predicted conceptual change as well as recall. Finally, both deep and shallow processing strategies mediated relations between mastery-approach goals and conceptual change.

Conclusions. Results provide some support for Dole and Sinatra’s (1998) Cognitive Reconstruction of Knowledge Model of conceptual change but also challenge specific facets with regard to the role of depth of processing in conceptual change.

In science learning, there is wide agreement that many students have inaccurate prior knowledge (i.e., misconceptions) about a variety of scientific phenomena (Diakidoy, Kendeou, & Ioannides, 2003; Kendeou & Trevors, in press; Kendeou & van den Broek, 2005, 2007; Mason, Gava, & Boldrin, 2008). Given the negative effects these
misconceptions can have on subsequent student learning, researchers have called for a conceptual change approach to addressing students’ misconceptions (diSessa, Gillespie, & Esterly, 2004). Conceptual change learning involves the restructuring of existing knowledge structures and the integration of new information into memory (Sinatra, 2005; Vosniadou, 1999, 2008).

Typically, research on conceptual change has focused primarily on the cognitive processes underlying conceptual change (Pintrich, Marx, & Boyle, 1993). Recently, researchers have noted that ‘conceptual change in the affective domain, particularly involving interests and motivation has had limited attention’ (Treagust & Duit, 2008, p. 300). This is especially concerning given that over 15 years ago Pintrich et al. (1993) called for more research that investigates ‘hot conceptual change’ by including ‘personal, motivational, social and historical processes’ (p. 170) in relation to conceptual change research. Specifically, they argue that in addition to traditional cognitive factors, motivational and affective factors (such as personal achievement goals) may be important mediators in the conceptual change process.

Although recent theorizing about conceptual change has led prominent researchers to emphasize the dynamic complexities underlying the various processes involved and the factors that influence conceptual change (Alexander & Sinatra, 2007; Murphy & Mason, 2006), few studies have explored the role that achievement goals play in conceptual change (Linnenbrink & Pintrich, 2002). Our study responds to this call. Specifically, the purpose of this study was to explore the direct and indirect effects of achievement goals on conceptual change learning. We examined the extent to which students’ achievement goals predicted use of deep versus shallow processing strategies, and whether and how these processes influenced conceptual change learning.

Importantly, we extend previous work in three ways. First, conceptual change researchers have made calls to explore dynamic and interactive aspects of conceptual change beyond mere outcomes. In this regard, we respond to researchers’ calls to combine quantitative approaches with qualitative, dynamic process-oriented designs (Sinatra & Mason, 2008) and examine ‘traces’ of individuals’ learning (i.e., data about actual studying events recorded while learners engage in a learning task; Winne, 1982; Winne & Perry, 2000) by including several measures of learning. Specifically, we examine the online processes that occur while students read new material, as well as offline products that occur after reading. Second, we explore one individual difference variable that is grounded in the ‘hot conceptual change’ literature by exploring how students’ achievement goals relate to the specific online process that we measure. In this regard, we extend Linnenbrink and Pintrich’s (2002) work by examining the specific types of learning strategies they use during learning rather than relying solely on self-report measures of these constructs. Finally, we provide empirical support for the importance of considering achievement goal theory within Dole and Sinatra’s (1998) Cognitive Reconstruction of Knowledge Model (CRKM) of conceptual change. To our knowledge, this important aspect has been empirically examined in only one other study (Taasoobshirazi & Sinatra, 2011). Prior to presenting our research questions and hypotheses, we first present the theoretical frameworks that informed our study and relevant empirical studies. We begin with conceptual change theory.
Theoretical frameworks

Conceptual change

Conceptual change research has become a prominent line of inquiry across diverse fields such as cognitive psychology, science education, and developmental psychology (Sinatra & Mason, 2008). Given the diverse perspectives on the issue, a number of models have been developed to explain how conceptual change occurs, what might facilitate or constrain that change, and how instructional interventions might help to foster change. We briefly introduce a few here. In one of the earliest models, Posner and colleagues (Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1983) presented conceptual change as a rational process involving assimilation and accommodation (see Piaget, 1974), wherein the focus is on the cognitive factors underlying change.

Like Posner et al.’s (1982) notion of accommodation, Chi’s (1992) model of categorical (ontological) shifts focuses on the re-categorization of concepts as the outcome of radical conceptual change. Similarly, according to Vosniadou (2007), conceptual change involves the restructuring of knowledge schemas such that fallacies are replaced with facts. Misconceptions arise when new information is not properly integrated into existing schemas, through assimilation or accommodation. Another model is diSessa’s (1988) phenomenological primitives model wherein a learner’s concepts are seen as a number of segregated fragments, or ‘knowledge in pieces’. In this model, diSessa argues that intuitive or naïve knowledge consists of hundreds of thousands of inarticulate explanatory primitives (p-prims) that are activated in specific contexts but are not broad enough to be considered theory- or schema-like (diSessa et al., 2004). Regardless of the model of conceptual change one adopts, it is clear that a large amount of effort is required to change one’s misconceptions and, as such, student motivation and depth of processing is paramount (Dole & Sinatra, 1998; Hynd, 2003; Pintrich et al., 1993; Sinatra, 2005).

In contrast to these ‘cold’ conceptual change models, Pintrich and colleagues (Pintrich et al., 1993) highlighted the need to include more ‘hot’ irrational factors in the change process, such as motivational, cognitive, and classroom factors. To extend the metaphor of ‘cold’ versus ‘hot’ conceptual change, Dole and Sinatra (1998) proposed the first ‘warm’ conceptual change model. In particular, in their model, they consider both ‘cold’ cognitive processes as well as ‘hot’ motivational factors in conceptual change. It is this model that we adopt for our study, which we describe in detail next.

The CRKM. Because of the focus on ‘hot’ and ‘cold’ factors as key to conceptual change, we adopted Dole and Sinatra’s (1998) CRKM. The CRKM can be considered a cognitive-developmental model of conceptual change as it is based on a theory or schema approach to conceptual change where naïve theories or misconceptions change into more sophisticated theories and more scientifically accurate conceptions (Vosniadou 2003; Vosniadou & Brewer, 1987). According to Dole and Sinatra, key to conceptual change is depth of cognitive engagement. For change to occur, one’s level of engagement must be high on the engagement continuum, which involves ‘deep thinking and processing of the information and reflection on one’s progression through the process’ (Dole & Sinatra, 1998, p. 125). Importantly, the CRKM explains that the message characteristics (i.e., characteristics of the to-be-learned material) interact with the learner’s characteristics (e.g., prior knowledge, motivation) to predict level of engagement with the new concepts.
As Sinatra (2005) noted, for conceptual change to take place, the message that students receive, either through instruction, group work, reading, or any other medium designed to promote change, must be comprehensible, coherent, plausible, and rhetorically compelling. Moreover, Sinatra cautions that if any of the aforementioned characteristics of the message are missing, then the likelihood of change occurring is extremely low. Clearly, the quality of the message is important for conceptual change to take place, but there are a number of learner characteristics that must also be present.

For learner characteristics, Dole and Sinatra (1998) divide these into existing conceptions or background knowledge and motivation. For the purposes of this study, we focus on the motivational component. Importantly, Dole and Sinatra (1998) include four facets of motivation relevant to conceptual change within the CRKM. (1) Dissatisfaction occurs when intuitive ideas conflict with scientific ideas, which creates a motive to harmonize these concepts through change. (2) The personal relevance of a topic can be based on interest in the topic, emotional involvement, or a stake in the outcome. (3) The social context of the learning experience can be highly motivating, particularly if the topic alone is not especially interesting. (4) ‘Need for cognition’ is the final motivational factor listed in the CRKM. Similar to learners who are intrinsically motivated, individuals high in need for cognition enjoy the challenges associated with learning and engage deeply with the material. For these four components, conceptual change is more likely among learners who are dissatisfied with their current understanding of a topic, when the topic is personally relevant, when their peers are interested and engaged in the topic, and when the student has a high need for cognition. Dole and Sinatra note, however, that they do not consider these four facets of motivation as the only relevant motivation elements of conceptual change. Although Dole and Sinatra do not explicitly include achievement goal theory in their model, we believe there are good reasons to explore this possibility (see also Taasoobshirazi & Sinatra, 2011). Before describing such reasons, we briefly present achievement goal theory.

Achievement goal theory
Achievement goal orientation explains the motives for behaviours in achievement activities (Ames, 1992) and is conceptualized under a $2 \times 2$ (Elliot & McGregor, 2001; Elliot & Murayama, 2008), or a trichotomous framework (Elliot & Church, 1997; Middleton & Midgley, 1997; Pintrich, 2000). Given the lack of empirical support for a mastery-avoidance orientation in the $2 \times 2$ framework (see Pintrich et al., 2003), we adopted the trichotomous framework. Under this framework, learners who adopt a mastery-approach orientation are motivated to develop competence, master skills, and recognize the intrinsic value of learning. Moreover, these learners strive to genuinely understand the material and believe that working hard will help them accomplish this goal. In contrast, learners who adopt a performance-approach orientation strive to demonstrate their ability to others such as the teacher or peers. Often, they compare themselves to others and focus on the self rather than the task at hand. Finally, a performance-avoidance orientation is characterized by learners who fear failing or looking incapable compared to others. These learners typically strive to avoid receiving negative feedback about their competence.

Incorporating achievement goal theory into the CRKM model
In light of Pintrich et al.’s (1993) call for more research on hot conceptual change, and the goal directed, intentional nature of changing one’s prior knowledge (Linnenbrink &
Pintrich, 2003), investigating motivational constructs in relation to conceptual change is clearly important. Specifically, Linnenbrink and Pintrich (2003) advise that achievement goal theory is particularly suitable for conceptual change research because achievement goals are situated, change according to the context, and go beyond individual differences. Furthermore, they suggest that achievement goals predict a number of motivational processes that are hypothesized to mediate conceptual change. Most significantly, Linnenbrink and Pintrich (2003) advise that since goals are a fundamental part of intentional conceptual change; achievement goal theory is an ideal motivational construct to consider when conducting conceptual change research.

There are a number of reasons why it is reasonable to investigate achievement goals within the context of the CRKM. First, there are similarities between the motivational components of the CRKM, namely personal relevance and need for cognition, and achievement goals. For instance, theoretically, personal relevance and mastery-approach goals share considerable overlap with the subjective task value construct found in Eccles et al.’s (1983) expectancy-value theory. This similarity is especially evident when one compares how subjective task values are measured (Wigfield & Eccles, 2000) and how mastery-approach goals have been conceptualized in the literature (Hulleman, Godes, Hendricks, & Harackiewicz, 2010). Although these concepts are distinct, theoretically, and even empirically, they are similar. More specifically, task values have been found to positively predict mastery-approach goals but not performance-approach and performance-avoidance goals (Lau, Liem, & Nie, 2008; Liem, Lau, & Nie, 2008). Similarly, mastery-approach goals have been found to predict utility value, with performance-approach goals showing no relationship (Hulleman, Durik, Schweigt, & Harackiewicz, 2008). There is also a logical link between mastery-approach goals and need for cognition.

Cacioppo and Petty (1982) define need for cognition as ‘the tendency for an individual to engage in and enjoy thinking’ (p. 116). Similarly, Ames (1992) defines mastery-approach learners as individuals who are ‘oriented toward developing new skills, trying to understand their work, improving their level of competence, or achieving a sense of mastery based on self-referenced standards’ (p. 262). Both constructs involve learning for its own sake. Although the positive affect component of mastery-approach goals is not obvious, recent work by Pekrun and colleagues (Daniels et al., 2009; Pekrun, Elliot, & Maier, 2009) suggests that positive affect is an important component of this construct and is an outcome and precursor to mastery-approach goals. Moreover, a positive correlation between need for cognition and mastery-approach goals has been reported in the literature (Hoffman & Nadelson, 2010).

One final reason why achievement goal theory is reasonable to investigate within the CRKM relates to their shared relationship with depth of processing. According to Liem et al. (2008), deep and shallow (or surface) processing is a typical way of conceptualizing level of cognitive engagement (Fredericks, Blumenfeld, & Paris, 2004). Deep processing involves going beyond the content to be learned through elaboration, critical thinking, and integration, while shallow processing involves simply memorizing and reproducing the content with minimal to no changes (Biggs, 1987). Depth of processing is at the heart of the CRKM, and an extremely popular topic within the achievement goal literature (for a review, see Senko, Hulleman, & Harackiewicz, 2011). Previous research has found that performance-approach goals positively predict deep processing (e.g., Liem et al., 2008) as well as shallow processing (e.g., Coutinho & Newman, 2008) whereas performance-avoidance goals have been found to negatively predict deep processing and positively predict surface (or shallow) processing strategies (Elliot & McGregor, 2001). Previous
research has also found that mastery-approach goals tend to positively predict deep (Bandalos, Finney, & Geske, 2003; Pintrich & Garcia, 1991; Senko & Miles, 2008) and even shallow processing strategies (Senko & Miles, 2008).

Accordingly, a student who is given a clear and coherent text to read (the message), and has a mastery-approach goal orientation for the content (learner characteristic), is predicted to be highly engaged, and should consequently experience higher levels of conceptual change. In contrast, a student who adopts a performance-avoidance goal orientation should fall low on the engagement continuum, and experience weak or even no conceptual change. Although the importance of depth of processing is intuitive, Dole and Sinatra (1998) noted that researchers have largely ignored the role that engagement plays in conceptual change. Consequently, they advised that further research on the role of motivation and depth of processing on conceptual change is needed to advance research in this area.

The present research
To date, few studies have explored relations between motivation from an achievement goals perspective and depth of processing in relation to conceptual change (Linnenbrink & Pintrich, 2002; Taasoobshirazi & Sinatra, 2011). According to Linnenbrink and Pintrich (2002), achievement goals relate directly to conceptual change by predicting distinct reactions to situations requiring conceptual change. In particular, mastery-approach oriented learners may engage in more conceptual change than learners who adopt alternative achievement goals due to their willingness to admit to mistakes. Admitting that one’s prior knowledge may not be accurate is a primary step towards conceptual change. In this regard, they predicted that a mastery goal orientation directly predicts conceptual change. We argue that admitting mistakes may also relate to the dissatisfaction component of the CRKM, which plays an important role in determining a learner’s level of engagement, and subsequently predicts the degree of conceptual change. As such, mastery goals may also indirectly predict conceptual change through depth of processing. This is also consistent with Dole and Sinatra’s (1998) prediction that depth of processing mediates relations between motivation and conceptual change.

In contrast, admitting dissatisfaction with current conceptions, or even that these conceptions are wrong, may be particularly difficult for performance-oriented students. Performance-oriented students generally adopt an ‘entity theorist’s’ view of learning (Dweck, 1986), which states that intelligence or competencies are fixed, whereas mastery-approach oriented students tend to adopt an ‘incremental theorist’s’ perspective and believe that competencies improve with practice. Consequently, admitting that one’s prior knowledge is incorrect when one adopts a performance goal orientation would be the equivalent of admitting that one is incapable of understanding a particular topic, and may lead to giving up. As such, Linnenbrink and Pintrich (2002) argued that performance goals directly negatively predict conceptual change. However, as noted above, depth of processing may mediate the relationship between motivation and conceptual change.

To empirically assess these hypotheses, Linnenbrink and Pintrich (2002) conducted two studies to investigate conceptual change in relation to achievement goals and depth of processing in students’ comprehension of Newtonian physics. As predicted, they found that mastery-approach goals were directly related to conceptual change, whereas performance-approach goals were not related to conceptual change. They also investigated the mediating role of affect, self-reported depth of processing (elaboration), and meta-cognitive strategy use to explore relations between these constructs. Results
indicated that mastery-approach goals were positively related to increased depth of processing, and a decrease in negative affect, which predicted greater conceptual change. Despite these findings, several theorists have identified issues with relying solely on self-report measures of learning behaviours (Muis, Winne, & Jamieson-Noel, 2007; Winne & Perry, 2000; Winne, Jamieson-Noel, & Muis, 2002). To address this, Winne et al. (2002) suggested researchers use traces, data about actual studying events recorded while learners study and solve problems. Moreover, Linnenbrink and Pintrich did not include the performance-avoidance goal, which may be an important goal to consider in terms of constraining conceptual change. We address these issues in the current study.

Beyond contributing to the CRKM, by incorporating the relationship between achievement goals and depth of processing, the present study takes an important step towards situating a common finding in the achievement goal literature within a particular theoretical framework. Furthermore, by situating the relationship between achievement goals and depth of processing consistently reported in the literature (for example, Liem et al., 2008, Lau et al., 2008) into the CRKM, we are building vertically on previous research by integrating findings from two different bodies of literature. Only the approach component of achievement goal theory has been integrated and empirically validated in the CRKM (Taasoobshirazi & Sinatra, 2011). Consequently, the present study addresses a finer grained analysis of the utility of incorporating achievement goals into the CRKM by investigating the outcomes associated with mastery-approach and performance-approach goals independently, and also including performance-avoidance goals. Moreover, we further test the two competing hypotheses that achievement goals are directly related to conceptual change (Linnenbrink & Pintrich, 2002) versus mediated through depth of processing (Dole & Sinatra, 1998).

Our study addresses these issues and assesses these two competing hypotheses by exploring relations between achievement goals, depth of processing, and conceptual change in the context of learning about Newton’s Laws using a think-aloud protocol. To set the stage for conceptual change to occur, and to potentially elicit dissatisfaction with current beliefs, we used refutational texts as a medium for presenting information about Newtonian mechanics. In the sciences, texts are often expository in nature, meaning that information is typically presented in a series-of-facts fashion. In contrast, a refutational text is used primarily to persuade students to change prior beliefs by explicitly identifying misconceptions and explaining the correct ideas (Alvermann & Hauge, 1989; Chambliss, 2002; Guzzetti, Snyder, Glass, & Gamas, 1993; Kendeou & van den Broek, 2005, 2007; Kendeou, Muis, & Fulton, 2011; van den Broek & Kendeou, 2008). Several studies on refutational texts have demonstrated their effectiveness in eliciting dissatisfaction and in helping learners acquire knowledge that is discrepant with what they already know (Alvermann & Hynd, 1989; Diakidoy et al., 2003; Maria & MacGinitie, 1987).

**Hypotheses**

Based on theoretical and empirical considerations, there are two plausible accounts of relations between achievement goals and conceptual change. First, consistent with the CRKM (Dole & Sinatra, 1998) and empirical work (Senko & Miles, 2008; Senko et al., 2011), we hypothesize that mastery-approach goals will positively predict shallow and deep processing strategies. We also expect that depth of processing will mediate relations between mastery-approach goals and conceptual change, and that deep processing strategies will positively predict conceptual change and recall, whereas shallow processing strategies will weakly predict conceptual change and recall. Specifically, in
line with the CRKM’s prediction that high levels of engagement should predict stronger conceptual change than lower levels, we expect deep processing to predict greater conceptual change than shallow processing. Additionally, given previous research (e.g., Senko & Miles, 2008), we predict that performance-approach goals will positively predict shallow processing strategies and recall performance, whereas performance-avoidance goals are expected to positively predict shallow processing strategies but negatively predict deep processing strategies and recall. Finally, given that prior knowledge is also an important factor in conceptual change (Dole & Sinatra, 1998), we hypothesize a positive relationship between prior knowledge and conceptual change.

In contrast, based on Linnenbrink and Pintrich’s (2002) hypotheses, we predict a direct relationship between mastery-approach goals and conceptual change given that, theoretically, mastery-oriented individuals may view mistakes as opportunities to correct those mistakes. In contrast, performance-approach and avoidance goals may be directly negatively related to conceptual change given the reactions that individuals may have when confronted with negative evaluative information (i.e., that their conceptions are incorrect; Linnenbrink & Pintrich, 2002). In this regard, individuals with performance goals may hold onto their misconceptions to a greater extent given that threatening information. Figure 1 presents the hypothesized model, which includes both direct and indirect relations between achievement goals and conceptual change. Solid lines represent expected positive relations, whereas broken lines represent expected negative relations.

Method

Participants

Seventy-three undergraduate students (N = 57 females) enrolled in various courses from several disciplines volunteered to participate in the study. Specifically, 26% were science, mathematics, or engineering majors; 38% were arts majors; 12% were social science majors; 11% were business majors; and the remaining 13% were undeclared. The mean age was 21.76 (SD = 3.95).

Materials

Prior knowledge and misconceptions

The Force Concept Inventory (FCI; Hestenes, Wells, & Swackhamer, 1992) was used to assess students’ prior knowledge relating to Newtonian physics. The FCI consists of 30 items that assess the overall understanding of the Newtonian concept of force, and can be used to identify and classify students’ misconceptions. The FCI is designed to get participants to choose between Newtonian concepts and common sense alternatives. Items consist of a multiple choice question with four or five possible options. Participants are asked to ‘choose the response that best answers or completes the situation described’. A sample item is, ‘Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be: (A) about half as long for the heavier ball as for the lighter one; (B) about half as long for the lighter ball as for the heavier one; (C) about the same for both balls; (D) considerably less for the heavier ball, but not necessarily half as long; (E) considerably less for the lighter ball, but not necessarily half as long’. To score the FCI, correct responses are
Figure 1. Hypothesized path model of achievement goals, depth of processing, recall, and conceptual change. Mastery = mastery goals; PAp = performance-approach goals; PAv = performance-avoidance goals; PK = prior knowledge; Deep = deep processing; Shallow = shallow processing. Dotted paths indicate hypothesized negative relationships and solid lines indicate positive relationships.
given one point, and incorrect responses are given a zero, with a highest possible score of 30 points. According to Hestenes et al. (1992), scores of 60% or less are indicative of misconceptions.

**Physics texts**

Two science texts were employed to increase amount of processing (e.g., each text was short, so two were used to increase time spent processing information to capture online learning strategies). The science texts consisted of short passages from Kendeou and van den Broek (2007), which were initially based on a college-level physics textbook (Hewitt, 2002). The texts were put onto cue cards and presented one sentence at a time so as to prevent participants from returning to previous sections. One text focused on Newton’s First Law of Motion, and the other focused on Newton’s Third Law of Motion. Both texts were comparable in word length (approximately 650 words each) and conventional readability indices. The average Flesch–Kincaid Reading Grade Level was 8.3.

**Conceptual change**

To examine the extent to which students’ misconceptions changed as a function of their achievement goals and depth of processing, students completed 14 of the original 30 items from the FCI (Hestenes et al., 1992), seven for each of the laws. These items were chosen specifically as they targeted students’ misconceptions about Newton’s First and Third Laws, and were explicitly discussed in the refutational texts. Each correct response was given one point, and each incorrect response was given a zero, with a maximum score of 7 points per law.

**Achievement goals**

The student version of the Patterns of Adaptive Learning Scale (PALS: Midgley et al., 2000) was adapted for this study and used to measure students’ mastery-approach, performance-approach, and performance-avoidance goal orientations. The PALS contains five mastery items (e.g., ‘It’s important to me that I learn a lot of new concepts’), five performance-approach items (e.g., ‘One of my goals is to show others that I’m good at this task’), and four performance-avoidance items (e.g., ‘It’s important to me that I don’t look stupid for this physics task’). Participants responded along a 5-point Likert scale ranging from 1 (not at all true) to a 5 (very true). Raw scores were then summed and averaged for each goal. Cronbach’s alphas reached acceptable levels for mastery-approach goals (α = 0.86), performance-approach goals (α = 0.93), and performance-avoidance goals (α = 0.90).

**Depth of processing**

A coding scheme was created to assess participants’ think-aloud comments for evidence of deep and shallow processing. In line with other scholars (e.g., Dole & Sinatra, 1998; Pintrich & Garcia, 1991; Stathopoulou & Vosniadou, 2007), deep processing strategies included those that involved learners’ attempts to integrate new ideas with their prior knowledge, organize and summarize ideas, and meta-cognitively engage. These three types of deep processing strategies were labelled ‘elaboration’, ‘paraphrase’,
and ‘metacognitive comments’, respectively. Transcribed comments were coded as *deep* if there was evidence of elaboration, meta-cognition, knowledge integration, or paraphrasing. These types of comments were linked with deep processing as they suggested that the participant made an effort to actively engage and learn the material in a meaningful way. For example, after being shown the following line of text, ‘According to Newton’s law, when the stone is dropped it will continue to move forward at the same speed as the walking person if no force acts to change its horizontal velocity’ the participant elaborated by stating, ’So, I guess possible forces that could change its horizontal velocity would be friction due to air resistance or something like that. Otherwise, it’s going to, you know, resist change in its motion. That’s the law of inertia’. For each transcript, every instance of elaboration, paraphrase, and metacognitive comments was allotted one point, and these scores were summed to yield a composite score for deep processing for each participant.

In contrast, participants’ statements were coded for evidence of shallow processing if they involved memorization of the new material, or the activation of prior knowledge without attempting to integrate it with new information. For example, after being shown the following line of text, ‘Newton reasoned that the same force acting on objects of different mass will produce different accelerations because force is a function of an object’s mass and acceleration’ the participant reiterated, ‘Okay, let me read this again. Newton reasoned that . . . ’. This type of shallow processing strategy is labelled ‘repetition/rehearsal’. For each transcript, every instance of repetition/rehearsal and association was allotted one point, and these scores were summed to yield a composite score for shallow processing for each participant. Two research assistants, blind to the hypotheses of the present study and who did not participate in the collection phase, randomly coded a subsection of the sample to establish inter-rater reliability, and then divided the rest of the coding between them. To calculate inter-rater reliability, the two raters compared the codes assigned to each think-aloud comment for 18 independently coded transcripts. Of the 146 transcribed texts, each rater coded a total of 82, with 18 of these texts overlapping between coders. Inter-rater reliability was acceptable ($K = 0.83$). Raters resolved code disagreements through discussion.

Recall achievement

Recall achievement was measured by asking participants to recall as much as they could from the text. Responses were coded by comparing what the participants wrote to the actual text such that responses were broken down into clauses and then matched to the text according to a ‘gist criterion’. Content that was recalled was compared to the original text in terms of the idea or meaning communicated by both passages, and thus did not have to be verbatim to be considered a match. For example, an original statement from the text was ‘The focus of this text is Newton’s first law, sometimes referred to as “the law of inertia”’. An example of a matched recall statement, based on the gist criterion, is, ‘This is about Newton’s first law, which is also known as the law of inertia’. Matches were allocated one point, and then summed to assign an overall recall score for each participant. Furthermore, if a participant repeated a previously recalled and correct statement, this recall would only count as one point. The highest score for Newton’s First Law of Motion was 33, and for Newton’s Third Law of Motion was 39, reflecting the total number of unique statements possible. Inter-rater reliability was established by comparing two raters’ independently coded texts. Reliability was acceptable ($K = 0.86$), and disagreements were resolved through discussion.
**Procedure**

Once participants consented to participate, a brief outline of the study, including the learning task and achievement task, was described. Participants then completed a demographics questionnaire, the FCI, and the PALS. Following this, participants were given specific instructions on how to read and think aloud (see Ericsson & Simon, 1993) and were provided a practice text on an unrelated topic about tornados. Once participants were comfortable with the think-aloud protocol, they were given one of two texts. The texts were counterbalanced to ensure there were no order effects.

Following each of the two think alouds, participants completed a mathematics worksheet to prevent rehearsal. Participants were then given a blank Microsoft Word document and asked to recall as much as they could remember from the text. Following the recall, participants were given a subset of the items from the FCI to measure changes in their misconceptions of Newtonian mechanics specific to the respective Law they had just read. The second experimental text was then given and all steps were repeated. The average length of the session was approximately 1 hr and 30 min and participants were compensated for their time. Think alouds were audio-recorded, transcribed, and then blindly coded (i.e., coders did not have knowledge of participants’ achievement goals). Recalls were also blindly coded in accordance with the aforementioned protocol.

**Results**

**Preliminary analyses**

Data were first screened for normality. All variables were normally distributed with skewness and kurtosis values within acceptable ranges; skewness ranged from –1.51 to 0.48, and kurtosis ranged from –0.40 to 3.43. Moreover, no order effects were found as a function of text order on recall performance or conceptual change. Means and standard deviations are presented in Table 1 for each of the subscales of the PALS, for deep and shallow processing, recall, and for conceptual change. Table 2 presents the correlation matrix.

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<th>Mean</th>
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Table 2. Correlations between each of the variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastery-approach</td>
<td>___</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance-approach</td>
<td>.39</td>
<td>___</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance-avoidance</td>
<td>.32</td>
<td>.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep processing</td>
<td>.25</td>
<td>.09</td>
<td>.21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shallow processing</td>
<td>.21</td>
<td>.16</td>
<td>.15</td>
<td>.86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCI pre-test</td>
<td>.07</td>
<td>.18</td>
<td>.12</td>
<td>.03</td>
<td>-.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FCI post-test</td>
<td>.22</td>
<td>-.26</td>
<td>.04</td>
<td>.35</td>
<td>.31</td>
<td>.59</td>
<td></td>
</tr>
<tr>
<td>Recall</td>
<td>.16</td>
<td>-.23</td>
<td>-.27</td>
<td>.28</td>
<td>.23</td>
<td>.29</td>
<td>.40</td>
</tr>
</tbody>
</table>

Note. *p < .001, **p < .01.

Path model

A path model was conducted to examine relations between constructs given that it is a more powerful and flexible approach to modelling relations between variables compared to regression (see Byrne, 2006). Our hypothesized model resulted in a poor fit, $\chi^2 = 118.94$, df = 11, $p < .05$, CFI = .78, RMSEA = .27. Accordingly, we removed three non-significant paths between performance-approach goals and shallow processing, performance-approach goals and recall, and performance-avoidance goals and shallow processing and reran the model. This second model, shown in Figure 2, resulted in a good fit, $\chi^2 = 119.08$, $p < .05$, CFI = .94, and RMSEA = .05. We also tested for mediation according to Preacher and Hayes’ (2008) bootstrapping technique, which is recommended with smaller sample sizes as it maintains higher levels of power while still controlling for Type I errors. Specifically, deep processing strategies were considered potential mediators between mastery and performance-avoidance goals and conceptual change, and shallow processing strategies were considered mediators between mastery goals and conceptual change. Conceptual change was entered as the criterion variable, mastery goals and performance avoidance goals were entered as the predictor variables, and deep and shallow processing strategies were entered as the mediators.

The bootstrap results revealed that the total effect of mastery goals and performance-avoidance goals on conceptual change became non-significant when the mediators were included in the model (direct effect of mastery goals and performance approach goals = 0.03, $p > .10$). Moreover, the analyses revealed, with 95% confidence intervals, that the total indirect effect of mastery and performance-avoidance goals on conceptual change through deep and shallow processing (for mastery only) was significant, with a point estimate of 0.02 and a 95% confidence interval (bias-corrected and accelerated) of 0.007 to 0.03. The specific indirect effects of each of the mediators demonstrated that deep processing strategies, with a point estimate of 0.005 and a 95% confidence interval of 0.001 to 0.015, and shallow processing strategies, with a point estimate of 0.008 and a 95% confidence interval of 0.0002 to 0.013, were both significant. We discuss these findings and their implications next.

Discussion

The goal of the present study was to advance understanding of conceptual change through achievement goal orientation and depth of processing. As predicted,
Figure 2. Final path model of achievement goals, depth of processing, recall, and conceptual change. Mastery = mastery goals; PAp = performance-approach goals; PAv = performance-avoidance goals; PK = prior knowledge; Deep = deep processing; Shallow = shallow processing. Dotted paths indicate negative relationships and solid lines indicate positive relationships.
mastery-approach goals were positively related to deep and shallow processing strategies (Senko et al., 2011; Senko & Miles, 2008) and to conceptual change (Linnenbrink & Pintrich, 2002), whereas performance-approach goals negatively predicted conceptual change. Performance-avoidance goals were also negatively related to conceptual change (Linnenbrink & Pintrich, 2002) and deep processing (Senko & Miles, 2008). Moreover, in line with the CRKM, prior knowledge positively predicted conceptual change such that individuals with higher levels of prior knowledge were more likely to change their misconceptions than students with lower prior knowledge. Deep and shallow processing also positively predicted conceptual change and recall. Finally, both deep and shallow processing strategies mediated relations between mastery-approach goals and conceptual change, and shallow processing strategies mediated relations between performance-avoidance goals and conceptual change. We discuss these relations in the context of the CRKM (Dole & Sinatra, 1998) and previous empirical work (Linnenbrink & Pintrich, 2002).

The CRKM
Consistent with Dole and Sinatra’s (1998) CRKM, the more that learners engaged in deep processing of the information, the more that conceptual change occurred; more so than when learners engaged in shallow processing, which was weakly related to conceptual change. Interestingly, although deep processing resulted in significantly more conceptual change than shallow processing, shallow processing was still related to conceptual change (as opposed to unrelated). To explain this, we present two plausible reasons. First, it is possible that the refutational nature of the information presented in the text was very powerful, and thus reduced the importance of depth of processing. If participants were able to clearly identify the dissonance between their held conceptions and the new conceptions that were introduced, then level (shallow or deep) of processing may not have been a particularly important factor.

For this explanation to be plausible, we consider a second facet of Dole and Sinatra’s (1998) CRKM. Under the CRKM, for conceptual change to take place, learner characteristics must interact with the message characteristics such that a high enough level of engagement (a deep level of processing) will occur, which makes conceptual change possible. For this study, we focussed on the role of the learner’s achievement goal orientation in conceptual change, and shallow processing was still related to conceptual change (as opposed to unrelated). To explain this, we present two plausible reasons. First, it is possible that the refutational nature of the information presented in the text was very powerful, and thus reduced the importance of depth of processing. If participants were able to clearly identify the dissonance between their held conceptions and the new conceptions that were introduced, then level (shallow or deep) of processing may not have been a particularly important factor.

The second plausible explanation is that the design of our study may not have been powerful enough to capture the full impact of depth of processing. Initially, shallow and deep processing may promote conceptual change, but deep processing may promote a longer lasting degree of conceptual change. A more robust measure of conceptual change might be a delayed post-test, such as 1 or 2 weeks after initial testing. This limitation reflects a shortcoming of not only the conceptual change and depth of processing literatures, but also one of the broader psychology literature (e.g., Hulleman et al., 2010; Linnenbrink & Pintrich, 2002), with notable exceptions (Phan, 2009; Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2009). Consequently, we recommend that future researchers investigate not only the degree of change immediately following
a learning task, but also the persistence of change over a longer period of time. Moreover, to establish causal links between achievement goals and conceptual change, we recommend that researchers manipulate the types of achievement goals that learners’ pursue (see Hulleman et al., 2010).

An additional recommendation for future research involves investigating how depth of processing and cognitive engagement are conceptualized. In line with the similarities between Dole and Sinatra’s (1998) definition of cognitive engagement and the depth of processing literature (e.g., Biggs, 1987), and with precedence in the literature (Fredericks et al., 2004), the present study did not distinguish between these two constructs. Nevertheless, further research needs to reduce confusion by clearly defining these constructs. Finally, we also recommend that future research explore how specific types of strategies predict conceptual change. Given that we dichotomized learners’ approaches as deep versus shallow, we did not assess whether one strategy was more effective at eliciting conceptual change than others. This may be a particularly fruitful line of inquiry.

**Implications**

Consistent with Linnenbrink and Pintrich’s (2002) findings, participants who reported a strong mastery-approach goal engaged in greater depth of processing and more conceptual change than participants who reported a weaker mastery-approach goal. In contrast to their findings that performance-approach goals were unrelated to conceptual change, we found that performance-approach goals negatively predicted conceptual change. Furthermore, the present study builds on this finding by showing a similar, albeit smaller, relationship between performance-avoidance goals and conceptual change. As noted by Linnenbrink and Pintrich (2002, 2003), one possible explanation for this finding is that performance-oriented students interpret attempts to correct their misconceptions as threats and, consequently, rather than changing their beliefs, they commit to these misconceptions even more. While personal relevance may account for the positive relationship found between shallow processing and conceptual change, this variable may also explain why performance-approach goals were negatively related to conceptual change. In the CRKM, personal relevance and dissatisfaction are key factors in determining whether conceptual change takes place (Dole & Sinatra, 1998).

Accordingly, it is plausible that when the message is not personally relevant, and performance-approach learners are satisfied with their current conceptions, they chose to minimize the negative emotional consequence of admitting that they were wrong, and thus decided to intensify their previously held belief (Linnenbrink & Pintrich, 2002, 2003), a course of action which may also be adopted by performance-avoidance learners. While strengthening misconceptions is a maladaptive behaviour, it is not without its affective benefits. When knowing the truth is deemed unimportant, and changing one’s beliefs results in negative affect, strengthening one’s misconceptions seems like a legitimate option. An alternative explanation for the negative relationship found between performance-approach oriented learners and conceptual change may relate to a lack of metacognitive awareness common among performance-oriented learners (Linnenbrink & Pintrich, 2003). Linnenbrink and Pintrich (2003) advise that since conceptual change is contingent on dissatisfaction of one’s prior knowledge, and since it is unlikely for performance-approach oriented students to identify the discrepancy between new information and their prior knowledge, then conceptual change for these individuals is improbable. Therefore by not identifying these important discrepancies, it is possible
that performance-oriented learners are simply encoding new ideas without integrating them with their prior knowledge, a behaviour that may explain this discouraging negative relationship. Although these explanations are credible, and could potentially provide an important perspective into the formation of misconceptions, data from this study cannot substantiate these claims. As such, we call on further research to investigate the role of personal relevance and level of satisfaction as important variables that potentially interact with performance-approach goals to promote the formation of misconceptions. Finally, although our results were consistent with some and divergent with other predictions from previous work, further research is clearly warranted. However, for now, with regard to conceptual change learning, we recommend that students seek to master the material and acknowledge misconceptions as opportunities to improve one’s understanding of the world around us.

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References


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