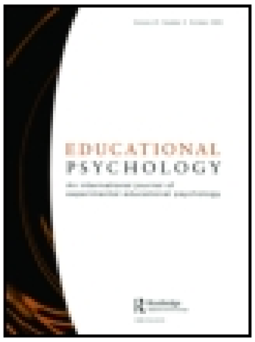

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The impact of group design projects in engineering on achievement goal orientations and academic outcomes

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ABSTRACT

This study examined the impact of incorporating group design projects into a second-year engineering class on achievement goal orientations and two academic outcomes: concept inventory and final exam scores. In this study, two sections were taught using lecture format, but one section also completed three group design projects as part of their curriculum. The intervention of incorporating group design projects had a positive effect on mastery goals and a negative effect on performance-approach goals. The effect of the intervention on academic outcomes was mediated by mastery goals but not performance-approach or performance-avoidance goals. Implications and future directions are discussed.

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Achievement goal theory; group design projects; engineering education; motivation

Attrition is an established problem in engineering programmes (National Academy of Engineering, [NAE], 2004; National Science Board, [NSB], 2007), and most college students who leave engineering do so in the first two years (Litzler & Young, 2012). Many factors contribute to students leaving (or staying in) engineering, such as high school experiences, family influences, study habits, coping strategies, teaching styles, interaction with faculty and peers and the connection (or lack thereof) between theoretical coursework and engineering practice (Baillie, 2000; Besterfield-Sacre, Atman, & Shurman, 1997; Litzler & Young, 2012; Suresh, 2006). During the first two years, engineering students typically take prescribed courses in math, science and engineering science that are often taught in large lecture-based formats. These important prerequisite 'barrier' courses can pose significant academic challenges that may partially explain retention problems in engineering (Suresh, 2006). Suresh (2006) found, through in-depth interviews, that the single most important predictor of student persistence in engineering was motivation to succeed (broadly defined) when the student faced difficulties. Interestingly, students' motivation to succeed directly influenced their intentions to persist in engineering but had little impact on their actual performance in barrier courses.

The use of project-based learning and the integration of design tasks early in the curriculum have both been recommended as changes that would benefit student retention in engineering majors (Mills & Treagust, 2003; NAE, 2005). Although incorporating project-based learning

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activities into engineering coursework has primarily been suggested in the context of giving students the chance to gain and develop complementary skills (NAE, 2005; National Research Council, [NRC], 2005; Schachterle & Vinther, 1996), the use of this instructional strategy may have the added benefit of encouraging students to adopt more adaptive orientations towards learning (e.g. learning to deepen understanding) instead of more maladaptive orientations (e.g. learning just to look good in front of peers). Lima, Carvalho, Flores, and van Hattum-Jansson (2007) found that project-based engineering tasks, according to both faculty instructors and students, increased students' motivation to learn as well as their teamwork skills, communication skills and connection to professional practice. Another benefit of incorporating group design projects into the curriculum is that these projects require students to persist in difficult tasks and normalise working through failure and within constraints (Lima et al., 2007).

This paper describes a quasi-experimental study in which group design projects were incorporated into one section of statics (lecture and projects) while, the same instructor taught another section without the addition of group design projects (lecture only). The instructional intervention centred on project-based learning that included design tasks and was chosen in an effort to help students recognise the connection between early coursework (such as statics) and engineering practices and to reduce emphasis on individual performance, while increasing cooperation (Geisinger & Raman, 2013). By introducing the group design projects the engineering instructor hoped to improve student content knowledge gains and motivation to succeed and stay in engineering. She partnered with an educational research team with the expertise to determine and apply appropriate theoretical frameworks to measure the impacts of the projects. At the time of the study, she was not aware of which theories were being used to assess the impact of the group design projects. Other companion studies examine how project-based learning impacts student intentions to stay in engineering and the role of communication in group performance. To understand the impact of project-based learning on student motivation and academic outcomes, we examined student motivation through the theoretical lens of achievement goal theory. This study illustrated how the relatively simple addition of projects to the curriculum could change student motivation even without the instructor being aware of achievement goal theory. In addition, this study was conducted in an authentic learning environment, not a lab setting, which makes the findings more generisable to typical classroom settings.

Theoretical framework: achievement goal theory

Achievement goal theory helps to explain how classroom structures influence student motivation and learning (Meece, Anderman, & Anderman, 2006). The cornerstone of achievement goal theory is the assumption that students want to be competent and/or display competence (Nicholls, 1984). These two dispositions are generally referred to as *mastery goal orientation* and *performance goal orientation*. Mastery goal orientation is associated with students desiring to learn new material and skills because they want to improve, and success is defined relative to the student's improvement. Performance orientation is associated with students desiring to demonstrate their ability relative to their peers, and success is defined relative to other students (Meece et al., 2006).

Both mastery and performance goal orientations have been further separated into two components creating a two-by-two framework for goal orientations: mastery-approach, mastery-avoidance, performance-approach and performance-avoidance. Mastery-approach is characterised by students wanting to deeply learn course material, whereas mastery-avoidance is characterised by students wanting to avoid not learning. Mastery-avoidance is the most recent addition to the achievement goal theory framework (see Elliot & McGregor, 2001), and because mastery-avoidance goals were not as salient to our research questions, we did not assess mastery-avoidance. Thus, we adopted the trichotomous framework of achievement goals, and mastery-approach goal orientation will be hereafter called simply mastery goal orientation. Performance-approach is characterised by the student wanting to look good in front of (appearance) or outperform (normative) peers. Performance-avoidance is characterised by the student wanting to avoid looking incompetent or displaying poor abilities in front of peers (Anderman & Wolters, 2006).

Mastery goals and academic outcomes

Mastery goals are positively associated with adaptive motivational outcomes such as choice, persistence, engagement, self-efficacy and deep study strategies (Grant & Dweck, 2003; Harackiewicz, Barron, Pintrich, Elliot, & Thrash, 2002; Hulleman, Schrager, Bodmann, & Harackiewicz, 2010). Given their relationship to these adaptive outcomes, mastery goals are also expected to have a positive relationship with academic outcomes (Grant & Dweck, 2003; Hernandez, Schultz, Estrada, Woodcock, & Chance, 2013; Taing, Smith, Singla, Johnson, & Chang, 2013). For example, Grant and Dweck (2003) found that mastery goals predicted course grades for students in a college level chemistry course and that deep processing mediated that relationship. Another study (Taing et al., 2013) found that mastery goals predicted higher goal setting and maintaining higher performance over time for psychology and business students. Hernandez and colleagues (Hernandez et al., 2013) found that, for under-represented minorities, mastery goals were predictive of grade point average (GPA) even after controlling for previous GPA.

Some have reported that mastery goals are not consistently found to be predictive of academic outcomes (Anderman & Wolters, 2006; Harackiewicz et al., 2002; Meece et al., 2006). However, the way that mastery goals are conceptualised and choice of instrument employed appear to influence the strength of the relationship (Hulleman et al., 2010). Additionally, students may pursue mastery goals for different reasons (Darnon, Dompnier, Delmas, Pulfrey, & Butera, 2009; Dompnier, Darnon, & Butera, 2009; Senko, Hulleman, & Harackiewicz, 2011). The antecedent of student mastery goal adoption could result in different outcomes. For example, some students may pursue mastery goals to please the teacher, while other students pursue mastery goals because they want to improve, with the latter being more strongly related to academic outcomes (Grant & Dweck, 2003).

Performance goals and academic outcomes

Unlike mastery goals, performance-avoidance goal orientations can be associated with maladaptive processes (e.g. reduced help seeking, cheating, self-handicapping, anxiety) and lower grades (Midgley & Urdan, 2001; Urdan & Midgley, 2001). However, performance-approach goals have been inconsistently linked to academic outcomes. Sometimes students with high-performance-approach goals demonstrate higher grades, while other students with high-performance-approach goals demonstrate lower grades. This contradiction has been the focus of much debate, and it appears that the contradiction is at least partially due to differences in the conceptualisation of performance-approach goal orientation (Grant & Dweck, 2003; Hulleman et al., 2010; Linnenbrink-Garcia et al., 2012). In a meta-analysis of achievement goal measures, Hulleman et al. (2010) categorised performance-approach goals into categories: (a) appearance – wanting to demonstrate ability relative to others, (b) normative –wanting to do better than others and (c) evaluative – wanting both to demonstrate ability and to be better than others. Appearance-framed performance-approach goals tended to be negatively related to academic outcomes, and normatively-framed performance-approach goals tended to be positively related to academic outcomes (Hulleman et al., 2010). In our study, we assessed the former.

Classroom environment

Since the inception of achievement goal theory, student goals have been distinguished from the goal structure of the classroom (Ames, 1992), but multiple studies demonstrate that students' goal orientations are influenced by how they perceive the goal structure of the classroom (Ames, 1992; Meece et al., 2006; Urdan, 2004). Students who have instructors who emphasise understanding and effort are more likely to adopt mastery goals, whereas students who have instructors who emphasise competition and social comparisons are more likely to adopt a performance orientation (Meece et al., 2006). Some research supports the environmental cue hypothesis that classroom level goal structures influence student goal orientation (Ames, 1992; Anderman & Anderman, 1999). In fact, the variation in student goal orientation attributable to student perception of classroom goal structure ranges from 5 to 35% (Meece et al., 2006).

Several elements can be manipulated in the classroom environment to emphasise specific types of goal orientations, which in turn encourage students to adopt a similar goal structure. The TARGET framework by Kaplan and Maehr (2007) suggests there are six domains that influence the type of goal orientation that students adopt – task, authority, recognition, grouping, evaluation and time. Project-based learning can easily accommodate aspects of encouraging mastery goals, such as having: (a) tasks that are meaningful and challenging and produce a useable product, (b) students who decide how to approach the task and (c) students who are recognised for risk taking, being creative, and learning from mistakes. Key features that define project-based learning include starting with a problem to be solved and an end product, such as a report, presentation or physical artefact (Blumenfeld et al., 1991). Project work is also more likely to be associated with the application of knowledge rather than the acquisition of knowledge (Helle, Tynjälä, & Olkinuora, 2006; Mills & Treagust, 2003) and can help make gaps in knowledge both apparent and difficult to gloss over (Helle et al., 2006). Thus, while projects are not necessarily designed to teach students new concepts and content, it can be difficult for students to apply an abstract concept to a real context without a deep understanding – or mastery – of the concept. Thomas (2000) pointed to the 'emphasis on student autonomy, collaborative learning, and assessments based on authentic performances' present in projects as features promoting mastery goals in students (p. 6). In addition, Schachterle and Vinther (1996) noted that projects might encourage students to learn because they can see how the information will be useful *now* rather than because they have been told that they will need this information at some ill-defined point in the future.

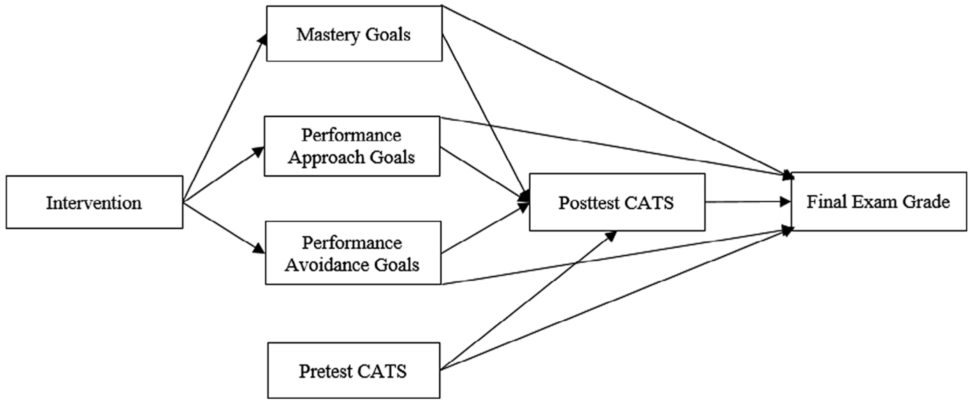

Figure 1. Model of the impact of the intervention on achievement goals and academic outcomes.
Notes: The following potential mediations were examined: (a) intervention ➔ mastery goals ➔ CATS, (b) intervention ➔ mastery goals ➔ CATS ➔ final exam, (c) intervention ➔ performance-approach orientation ➔ CATS, (d) intervention ➔ performance-approach orientation ➔ CATS ➔ final exam, (e) intervention ➔ performance-avoidance orientation ➔ CATS and (f) intervention ➔ performance-avoidance ➔ CATS ➔ final exam. CATS is the Concept Assessment Tool for Statics.

Research questions

Our study examined the impact of the integration of group design projects on student achievement goals and, subsequently, on academic outcomes. This study examined group differences in achievement goals for students taking Statics, a second-year engineering course, in the intervention and comparison sections. Traditionally viewed as a barrier course, statics covers applications of Newtonian mechanics, is one of the first engineering courses for civil and mechanical engineering students, and is a gateway course for many upper-level engineering courses. The two academic outcomes were the Concept Assessment for Tool for Statics (CATS; Steif & Dantzler, 2005) and the final exam. Student consent was obtained before any data were gathered.

We asked two research questions. First, does the use of mastery framed group design projects influence the achievement goal structure adopted by students? Second, do any of these achievement goals mediate the effect of the intervention on academic outcomes? Given the prior literature, we hypothesised that mastery framed goals would positively influence the adoption of mastery achievement goals, and the mastery achievement goals would positively predict academic outcomes. Therefore, we tested the potential mediation paths shown in Figure 1.

Methodology

Participants

Students in two sections of statics were recruited. Students were unaware of the study when they registered for the course and, as the sections were both full at the start of the semester, the department prevented students from switching sections after they learned about course activities. One section was taught on Monday, Wednesday and Friday at noon and the other section was taught on the same days at 1 pm. The same instructor taught both sections in an effort to eliminate differences associated with instructor. To ensure that the lectures by the instructor were as similar as possible in both sections, instructional materials and schedules were shared with the entire research team and the graduate teaching assistant for review. Also, the instructor of both sections was not aware of achievement goal theory at the time of the study.

In the comparison section (the course taught with lecture only), 108 of 115 students consented to participate, and 101 of 112 students consented to participate in the intervention section (the course taught with lecture and projects). Within the comparison section 86% of the students were male and 5% identified as ethnic minorities, and within the intervention section 77% of the students were male and 7% identified as ethnic minorities. The students in the comparison section were largely mechanical engineering majors (52%) followed by civil engineering majors (32%) and environmental engineering majors (11%). The students in the intervention section were also mostly mechanical engineering majors (46%) followed by civil engineering majors (30%) and environmental engineering majors (16%). For students for whom GPA information was available, an independent sample *t*-test indicated that upon entering statics the students in the intervention and comparison sections did not have different GPAs (t (186) = .18, p = .86). Further, chi-square tests revealed no statistically significant differences in the sections on ethnicity (χ^2 [df = 7] = 4.81, p = .68), sex (χ^2 [df = 1] = 2.57, p = .11) or major (χ^2 [df = 7] = 3.87, p = .80). Chi-square analyses indicated that the students with complete data and those with some missing data did not differ on ethnicity (χ^2 [df = 7] = 6.12, p = .53), sex (χ^2 [df = 1] = .99, p = .32), or major (χ^2 [df = 7] = 5.96, p = .55). This study was part of a larger study that examined the impact of group design projects on student learning, development into an engineer, and motivation. No differences were found on other pretest variables for the other psychological processes assessed, such as engineering identity (t (173) = .59, p = .56), attitudes towards engineering (t (173) = 1.57, p = .12), self-efficacy (t (173) = .13, p = .90), outcome expectations (t (173) = .53, p = .59) and intentions to persist in engineering (t (173) = .31, p = .76; Atadero, Rambo-Hernandez, & Balgopal, 2015).

Procedure

The comparison section was taught in a traditional lecture format, and a student response system (i.e. clickers) was used during lecture. Course grades were assigned based on homework assignments from the textbook (15%), three mid-term exams (15% each), clicker questions (8%) and a final exam (30%). The intervention section was also taught in a lecture format, and clickers were also used to assess students. Course grades in the intervention section were assigned based on homework assignments from the textbook (13%), three mid-term exams (10% each), clicker questions (5%) a final exam (20%) and three group design projects (10% each). The two sections generally had the same lecture and took the same exams. In the project-based section, a few lectures were cut short so that groups could meet for roughly 15–20 min during class time for each of the projects. The project presentations were made during the evenings during the scheduled exam time. In this way it was possible to keep the two classes in sync for the semester. The two lectures did differ on occasion based on the need to address different student questions. In both sections a small percentage of the grade (2%) was based on participation points, which students could earn by completing the pre and post assessments for this study. Alternative assignments were provided for those students not participating in the research project to earn these participation points.

Lecture in the intervention section was also distinguished from the comparison section on the first two days of the semester. On the first day the sections were presented with their respective syllabi, and students in the intervention section learned that they would be expected to work in teams on three group design projects during the course of the semester. The second half of this first day was devoted to gaining informed consent for the study in both sections. On the second day of class the comparison section started with a description of how statics is useful and then reviewed units of measurement and vectors. This day in the intervention section was devoted to a lecture on the engineering design process, introducing the first design project, and assigning student groups for this project. This lecture was intended to help set the tone for the semester by emphasising that the course was an *engineering* course and during the semester students would be expected to act as design engineers during their three group design projects. By discussing design before we introduced statics concepts we hoped to help students recognise the importance of the course content in their future profession and to provide a context where students would apply what they were learning. Otherwise, during the course of the semester the two sections generally followed the same schedule, discussed the same topics, and worked through the same example problems each day.

The course material was loosely clustered into three units. Students in the intervention section participated in a group design project for each of the three units. For each project, student teams were required to design and construct an artefact, demonstrate its operation to the class, and prepare a report including a description of their design process and the calculations/analysis they conducted of their design. Students worked in teams of approximately five students assigned by the instructor and were assigned to new teams for each project. Students were aware of evaluation expectations after receiving rubrics in class on the same days the projects were assigned. Project grades were assigned primarily based on the content of the group report, with roughly 20–30% of the grade based on the operation of the design during the presentations.

The group design projects were designed for authentic assessment. They were introduced at the beginning of each unit to increase student motivation to learn the necessary theoretical concepts needed to complete the projects. The first unit covered equilibrium; the project task was to build a Rube Goldberg machine that would raise a team flag. Each team member was a 'design engineer' for one component of the machine. The second unit focused on applications of equilibrium with topics such as trusses, frames, machines and beams. Student teams designed and built a bridge using only basswood sticks and string that the instructor provided. The bridge was required to span a distance of .61 m (2 feet) and was loaded via point load at the mid-span of the bridge until failure. The third unit covered friction; student groups were given dimensions of a ramp and asked to help the school mascot climb the 'mountain' using friction to their advantage.

Instrumentation

During the second week of the semester, students in the intervention and comparison sections took the CATS (Steif & Dantzler, 2005) and the Patterns of Adaptive Learning Scales Revised (PALS; Midgley et al., 2000) online. The same instruments were administered again in the next to last week of the semester. The final exam was administered during finals week during the university assigned times for each section; each student took one of four versions of the final exam. Versions A and B were administered in the intervention section. These exams had the same six problems, but numbers were changed between the two versions. Versions C and D were administered the following day in the comparison section. Three of the problems were the same as versions A and B with only different numbers. For the other three problems, the same concepts were covered, but new figures were provided and the questions were modified accordingly.

CATS. Because students were not assigned a performance grade but rather a completion grade, the CATS was a low-stakes assessment of mastery of statics content. The CATS has been shown in previous studies to have adequate reliability and evidence of validity (Steif & Dantzler, 2005).

PALS. The PALS-revised (Midgley et al., 2000) was designed to measure the trichotomous framework of achievement goal theory: mastery, performance-approach and performance-avoidance goals. The PALS-revised is one of the commonly-used scales to assess student achievement goal orientations and uses appearance-related language to performance-approach goals. A measurement concern raised by Linnenbrink-Garcia et al. (2012) was that the studies using the PALS tend to report higher correlations between performance-approach and avoidance than other achievement goal instruments (Linnenbrink-Garcia et al., 2012). The strength of the correlation could be due to students not discriminating between appearance-based performance-approach and avoidance items, e.g. the desire to look good in front of peers may not be readily distinguishable from the desire not to look bad in front of peers. If the correlation were high, one solution offered by Linnenbrink-Garcia et al. (2012) was to drop one of the constructs from consideration. The correlation between the two constructs was indeed high in our sample, which may indicate that students in this study did not readily distinguish between the two constructs. However, because we could explicitly model the correlation between the two constructs in our analyses, we decided to retain both performance-approach and performance-avoidance goals in our statistical model. Additionally, the path coefficients in the model were similar to the zero-order correlations, thus, suppression effects are not a concern.

The mastery goals scale contained five items such as, 'It's important to me that I thoroughly understand my class work'. The performance-approach goals scale contained five items such as 'It's important to me that I look smart compared to others in my class'. The performance-avoidance goals scale contained four items such as 'It's important to me that I don't look stupid in class'. Students responded on a scale from 1 (strongly disagree) to 5 (strongly agree) for both scales. The reliability of each scale was high (Table 1).

Plan of analysis

The pre-test and post-test CATS, achievement goals at the end of the semester, and final exam scores were examined using a path analysis to determine the effect of the intervention on student achievement goals and then achievement goals on student academic outcomes (Figure 1). All analyses were conducted using full information maximum-likelihood estimation in M*plus* version 7.11 (Muthén & Muthén, 1998–2012). We employed a model building approach where we first built a saturated model that included all paths specified in Figure 1 and all possible paths of observed variables on previously observed variables

Table1. Correlations and reliability of pre- and post-achievement goal orientations and assessments.

		1	2	3	4	5	6	7
1	Intervention	–						
2	Pre-test CATS	.10	–					
3	Mastery orientation	.19	.07	–				
4	Performance-approach orientation	−.07	−.03	−.12	–			
5	Performance-avoidance orientation	−.15	.03	−.08	.81***	–		
6	Post-test CATS	.01	.46***	.19*	−.14	−.10	–	
7	Final exam	.05	.29***	.01	−.08	−.05	.30***	–
	N	–	–	171	171	171	–	–
	Reliability	–	–	.87	.87	.76	–	–

Note: $^*p < .05$; $^{**}p < .01$; $^{***}p < .001$

Table 2. Descriptive statistics of initial and ending achievement goal orientations and assessments by section.

	Comparison			Intervention		
	N	Mean	SD	*N*	Mean	SD
CATS pre-test	101	22.15	9.73	85	24.53	13.29
Mastery goals	83	3.97	.59	87	4.18	.56
Performance-approach goals	83	2.87	.86	87	2.61	.87
Performance-avoidance goals	83	2.92	.86	87	2.80	.81
CATS post-test	90	32.76	15.92	94	33.18	16.64
Final exam grade	98	63.70	10.23	94	64.72	11.03

(e.g. intervention ➔ CATS post-test). For the final model, we retained all originally specified paths of interest (see Figure 1) and any statistically significant paths that were not in the original model. Several indicators were used to determine if the model was a good fit to the data. Specifically, the most common indication of good model fit in a non-significant chi-square. However, because chi-square is sensitive to sample fluctuation, we also used the comparative fit index (CFI) above .95 and a root-mean-square error of approximation (RMSEA) value below .06 or a confidence interval that contained .06, and the standardised root-mean-residual (SRMR $\leq$ .08) to indicate acceptable model fit (Browne, Cudeck, & Bollen, 1993; Hu & Bentler, 1999).

Next, we examined the effect of the intervention on academic outcomes through achievement goal orientations. Specifically, we addressed research question 1 by examining the regression paths between the intervention and the three achievement goal variables. For research question 2, we tested to see if the effect of the intervention on mastery of statics content (i.e. CATS) was mediated by mastery goals, performance-approach goals and performance-avoidance goals and if the effect of the intervention on the final exam was mediated by mastery goals, performance-approach goals and performance-avoidance goals and mastery of statics content (i.e. CATS). This indirect effect is a product term and thus not normally distributed, so we used a bootstrapping procedure with 10,000 repetitions to create a 95% confidence interval around the indirect effect (MacKinnon, Fairchild, & Fritz, 2007; Shrout & Bolger, 2002).

Results

Based on the descriptive statistics (Table 2), students in the intervention section appeared to have higher mean mastery goals but lower performance-approach goals and

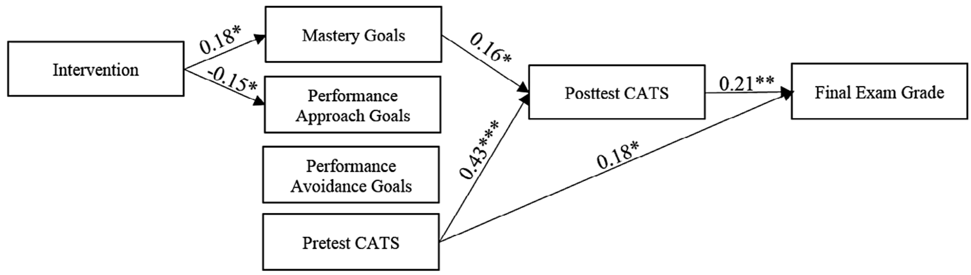

Figure 2. Path analysis results of the impact of the intervention on achievement goal orientation and academic outcomes.

Notes: Standardised results presented. Only statistically significant paths are presented. CATS is the Concept Assessment Tool for Statics. $p < .05$, $^{**}p < .01$, $^{***}p < .001$.

performance-avoidance goals when compared to the comparison section. An examination of the correlation matrix revealed some expected as well as unexpected relationships (Table 1). As expected, the pre-test CATS, post-test CATS and final exam scores were all positively related with each other. Of note, only mastery goals scores were positively related to post CATS scores, and no goals were related to final exam scores. Also of note, the intervention was not related to pretest CATS scores, which indicated that there were no content knowledge differences between the two sections at the beginning of the semester.

Model Fit. In the model building process, a saturated model was run with all possible paths included. The saturated model did not reveal any additional statistically significant paths that should be added to the theorised model in addition to the originally specified paths in Figure 1, therefore, only the original model is discussed hereafter and serves as the final model.

Not every path that was included in Figure 1 was statistically significant. Although the final model included paths that were statistically significant and paths that were not statistically significant, for simplicity, only the statistically significant paths are shown in Figure 2. Thus, we examined the final model fit against the a priori standards. The final model provided an acceptable fit to the data (χ^2 [df = 6] = 6.40, $p = .38$, CFI = 1.00, RMSEA = .018, 90% CI [.000, .093] and SRMR = .023).

Research question 1: testing the effect of the intervention on achievement goals

The intervention was positively related to mastery goals scores ($\beta = .18$, $b = .21$, SE = .089, $p = .02$) and negatively related to performance-approach goals ($\beta = -.15$, $b = -.26$, SE = .132, $p = .048$). However, the intervention was not related to performance-avoidance goals ($\beta = -.07$, $b = -.12$, $SE = .127$, $p = .35$).

Research question 2: testing the mediation of the intervention on academic achievement through achievement goals

Mediation of the intervention on academic achievement through mastery goals

We first examined the potential mediation of the intervention on posttest CATS through mastery goals: intervention ➔ mastery goals ➔ post-test CATS. Before testing the mediation hypothesis, we needed to establish that each of the paths in the mediation was statistically significant. Having already established that the intervention had a positive relationship with mastery goals scores, we proceeded to examine the remaining paths. All remaining paths were positive and statistically significant (Figure 2), namely mastery goals on post-CATS scores ($\beta = .16$, $b = 4.33$, SE = 1.79, $p = .02$). Therefore, we proceeded to test the indirect effect of the intervention on post-CATS scores through mastery goals. The bootstrapping procedures revealed that the indirect effect was statistically significant ($\beta = .028$, $b = .91$, 95% CI [.17, 2.37]). The statistically significant indirect effect indicated that the effect of the intervention on post-CATS scores was at least partially mediated by mastery goals.

For the second academic outcome, we hypothesised that the effect of the intervention on final exam scores would be mediated by mastery goals and post-CATS scores, a low-stakes measure of mastery of statics content (intervention ➔ mastery goals ➔ posttest CATS ➔ final exam scores). We already established in the previous mediation analysis that the two paths in the hypothesised mediation were statistically significant, so we tested the third and final path, post-CATS on final exam scores. This path was statistically significant ($\beta = .21$, $b = .14$, SE = .053, $p = .008$), so we proceeded with the mediation analysis. Using the same bootstrapping procedure previously described, the indirect effect was statistically significant ($\beta = .006$, $b = .127$, 95% CI [.020, .427]).

Mediation of the intervention on academic outcomes through performance-approach and performance-avoidance goals

We examined the indirect effects of the intervention on academic outcomes through performance-approach goals. Because the path from the intervention to performance-avoidance goals was not statistically significant, performance-avoidance goals could not mediate the relationship between the intervention and any academic outcome. Further, the path from performance-approach goals to post-test CATS was not statistically significantly (Figure 2). Because the indirect effect of the intervention on post-test CATS and final exam must go through this path (i.e. intervention ➔ performance-approach orientation ➔ post-test CATS, and intervention ➔ performance-approach orientation ➔ post-test CATS ➔ final exam), performance-approach goals could not mediate the relationship between the intervention and any academic outcomes. Therefore, these tests of mediation were unnecessary.

Discussion

Students graduating from engineering programmes need a variety of skills, yet most US engineering programmes currently emphasise the analytical and technical skills necessary for engineering practice (NSB, 2007). Outcomes focusing on complementary skills often receive less attention (Lucena, 2003). Group design projects are one way to incorporate technical and needed professional skills such as communication, teamwork and independent learning into the same assignment. This study indicated that projects are an instructional tool that not only address achievement of a variety of student outcomes but also promote mastery motivations for learning that have positive effects on academic outcomes. Even though the instructor was unaware of achievement goal theory at the time of the study, the addition of group design projects was able to influence student motivation. The three findings of particular interest are (a) the intervention was related to increases in mastery goals and decreases in appearance-framed performance-approach goals (b) mastery goals mediated the effect of the intervention on the concept inventory (CATS), and mastery goals and concept inventory scores mediated the effect of the intervention on final exam scores and (c) performance-approach and performance-avoidance goal orientation scores did not mediate the effect of the intervention on either academic outcome.

Group design projects appear to have had the desirable effect of increasing student mastery goals, and group design projects also decreased appearance-framed performance-approach goals. Previous research has shown that the course activities and grading structure encourage students to adopt particular achievement goal orientations (e.g. Karabenick & Collins-Eaglin, 1997; Meece et al., 2006). In this study, incorporating group design projects that highlight mastery goals had the ability to impact student achievement goals. Previous research has not examined what effect group design projects would have on the adoption of appearance-framed performance-approach goals, and our results indicate that students did endorse these goals at lower rates than students in the traditional lecture-based course. These lower rates of endorsement of performance-approach goals may, in fact, have been a by-product of the mastery-based intervention. Multiple studies have demonstrated students align their achievement goal orientations to match the goal structure of their classroom (Anderman & Anderman, 1999; Meece et al., 2006). Introducing group design projects highlighted mastery goals and may have changed the goal structure of the classroom, such that students performance-approach goals were less salient (e.g. students presented their projects in groups not individually, so there was little external incentive to outperform others). Additionally, these lower rates of endorsing appearance-framed performance-approach goals may, in fact, be a desirable outcome. For example, performance-approach goals have sometimes been linked to lower academic performance (Hulleman et al., 2010), increased test anxiety (Linnenbrink, 2005), and likelihood of cheating (Tas & Tekkaya, 2010).

Furthermore, compared to creating new courses and revamping curricular coursework, incorporating a few discrete projects within a lecture-based course is a very manageable curricular change in gateway engineering classes that may have broad benefits in moving students towards mastery goals. This is important because, in spite of the benefits of integrating group design projects in courses, many engineering educators are hesitant about adopting such changes (Lucena, 2003). Reasons for this resistance vary. For example, Fairweather (2008) found in his review of NSF-funded projects to improve undergraduate STEM instruction, engineering faculty members often reject curricular reforms that promote problem-solving because they assume changes will be too time consuming. Or perhaps, educators believe that, in order to implement group design projects, they must abandon all direct instruction (lectures). Kirschner, Sweller, and Clark (2006) argued that although there are advocates for both direct instruction and for minimally guided instruction, the research indicates that science (and we would expect all STEM) learning outcomes are not necessarily greater when there is minimal guidance. They noted that students need some level of guidance to demonstrate learning gains. In this study, we demonstrated that using lecture along with fairly open-ended and easy to implement group design projects produced changes in mastery goal orientation, which then impacted student mastery of content. Lima et al. (2007) reported that, although modifying the syllabus, lectures, assessments and types of instructional guidance required effort at the onset, engineering instructors reported that the benefits to student content learning and communication skills were worth integrating project-based learning into their courses. Given the positive outcomes achieved in this situation where discrete projects were added to a lecture-based course, we hope that more engineering educators will be willing to try modest changes.

The next finding of note is that the intervention had an effect on student performance on the concept inventory (CATS) through mastery goals and on the final exam through mastery goals and the concept inventory. However, similar to other studies (Hulleman et al., 2010), mastery goals scores were not directly related to performance on the final exam. The effect of mastery goals on the final exam was mediated through the low-stakes concept inventory CATS. Thus, it appears that the deeper understanding fostered by a mastery goals translated to an indirect impact on exam scores that was only noticeable via the low-stakes CATS assessment. We speculate that on high stakes assessments, like final exams, that mastery goals may only be one of many factors that cause increases in scores and harder to separate from other unmeasured factors, e.g. study habits. However, when we were able to tease out the effect of mastery goals on content knowledge through a low-stakes test (one that students were unlikely to study to take) the effect of a mastery goals on scores was evident. A low-stakes assessment may prove to be an important addition to models that assess the impact of how mastery goals are academic outcomes.

Finally, even though other studies have shown that appearance-framed performance goals are sometimes related to lower academic performance (Darnon et al., 2009; Hulleman et al., 2010; Midgley & Urdan, 2001; Urdan & Midgley, 2001; Linnenbrink-Garcia et al., 2012), performance-approach and performance-avoidance goals were unrelated to academic outcomes in this study. One possible explanation was an issue with measurement because of the high correlation between performance-approach and performance-avoidance goals (Linnenbrink-Garcia et al., 2012). The PALS-revised was not sensitive enough separate performance-approach and performance-avoidance goals for students in this sample. Other scales such as the Achievement Goal Questionnaire (AGQ) use items to assess performance-approach orientations that are more normatively focused and consequently yield positive correlations with performance (Hulleman et al., 2010). Future studies should consider using a more nuanced scale that assesses appearance-framed performance-approach and performance-avoidance and possibly by adapting the PALS-revised scale to be more sensitive to the classroom context.

Limitations and future research

Because we introduced the course syllabus prior to data collection, we were not able to establish a baseline for the achievement goal orientations for the two sections prior to the implementation of the intervention. Further, students were not randomly assigned to intervention, but there are multiple reasons to suggest that students in the two sections did not differ on achievement goal orientations prior to beginning the course: (a) no differences in student characteristics or other psychological processes were observed between the two sections; (b) students were unaware of the study when they registered for the course and were prohibited from switching sections; and (c) both courses were taught three days a week, one hour apart. However, the observed differences in achievement goal orientations between the two sections at the beginning of the semester may not have been due to exposure to the structure of the course (e.g. syllabus) but could have existed prior to the beginning of the semester. A second limitation is that students in the intervention section knew that their section was different and may have responded differently simply because they knew they were being treated, i.e. a Hawthorne effect. Another limitation is that student data were collected only at the beginning and end of the semester. Additionally, the instrumentation was somewhat problematic. In particular, the final exam was not subjected to a psychometric analysis for evidence of reliability and validity. Also because of concerns that students might share answers, we used different versions of the final exam in each course. Further, we did not report alternate statistically equivalent models.

Another potential limitation is that the students in the two different sections of statics likely spent different amounts of time on their coursework as the section with projects had the same lectures and textbook problem assignments as the comparison section without projects. The effect of time on task on motivation is not known; however, time on task has been shown to be only weakly correlated with academic performance for college students (Guillaume & Khachikian, 2011Nonis & Hudson, 2006; Plant, Ericsson, Hill, & Asberg, 2005). Finally, only two sections of statics were offered and eligible to be used for the study. If more sections were taught concurrently, we would be able to randomly assign students to different treatment groups; however, then we would have added a confounding factor of instructor with treatment. Also, future studies may want to wait to introduce design until after initial data collection is complete to establish baseline data and determine if the course structure alone is sufficient to invoke higher levels of mastery goals.

Further studies that examine the impact of project-based learning on achievement goal orientation are needed. For example, studies could be conducted to see how emphasising mastery goals in early engineering courses, such as introduction to engineering, impacts mastery goals in other engineering prerequisite courses, such as calculus or physics. In particular, longitudinal studies are needed that examine changes in orientation as students participate in project-based learning and how these changes may or may not persist as students enrol in other courses with and without project-based learning. Also, other longitudinally studies are needed that examine the impact of implementing project-based learning throughout several courses on student goals and eventual careers. Additionally, more studies that examine the particular aspects of project-based learning to determine which aspects are critical to success and which may be dispensable are warranted.

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