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ORIGINAL PAPER

Motivational climates: assessing and testing how science classroom environments contribute to undergraduates' self-determined and achievement-based science goals

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Abstract The current research examined the psychometric properties and utility of a measure of college classroom environment in predicting goal-related outcomes rooted in goal contents and achievement goal theories. Exploratory and confirmatory factor analyses in Studies 1 and 2, respectively, yielded support for two distinct and gender-invariant classroom environment constructs—professorial concern and affiliation. Results of multilevel regression analyses in Study 3 indicated that both constructs were positive predictors of intrinsic and self-approach goals. Additionally, professorial concern was a significant positive predictor of extrinsic goal adoption. Contrary to expectation, perceptions of affiliation in the science classroom were unrelated to task-approach goals. These findings illustrate the important role that socially dynamic classroom contexts play in fostering motivation and satisfying basic needs for autonomy, competence, and relatedness.

Keywords Achievement goal theory · Classroom environment · Extrinsic goals · Goal contents theory · Intrinsic goals

Introduction

Motivation matters. We have probably all seen the student who, despite high grades and positive feelings of efficacy and confidence, wants to drop a class or switch majors because he or she lacks the motivation to continue. This is especially troubling when the student is in a high-need field (e.g. science or engineering) or is from an underrepresented group (e.g. women). What forces shape such a student's motivational experience in the classroom?

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Theorists have long acknowledged the important role that the environment plays in shaping human development (e.g. Bronfenbrenner 1979) but few theories of this sort have actually addressed the mechanisms by which environments specifically influence motivation. How does the classroom situation influence a student's motivation? In what ways does a given context support or undermine motivation? In the present research, we integrated research from self-determination theory (SDT; Deci and Ryan 1985; Ryan and Deci 2000) and achievement goal theory (Harackiewicz and Elliot 1993; Elliot and McGregor 2001) to shed light on the complicated motivational processes within the science classroom.

Goal contents theory: intrinsic and extrinsic goals

The personal and sociocultural factors that impel people to strive for growth and well-being have been the focus of scholarly inquiry for decades. SDT provides a framework for understanding optimal functioning by proposing that people strive to satisfy fundamental needs for competence, relatedness and autonomy. Because conditions within the environment can facilitate or thwart the satisfaction of these needs, behaviour can be experienced as volitional and autonomous, or as controlling and determined by external contingencies (Ryan and Deci 2000). SDT is a complex meta-theory of motivation with six mini-theories (for review, see Deci and Ryan 2012). We drew on goal contents theory, a sub-theory of SDT which focuses on goal pursuit as an alternative route to need satisfaction (Deci and Ryan 2008). Whereas SDT motives reflect the regulatory processes by which psychological needs are met, goals contain information about end states that serve to organise and direct behaviour towards the experience of positive affect (Fishbach and Ferguson 2007). Anticipation of the experience of positive affect, or the minimisation of negative affect, thus exerts an important influence on motivated self-regulation (McClelland et al. 1953). Kasser and Ryan (1993, 1996) have identified two types of goals reflecting the classic intrinsic–extrinsic dichotomy. Intrinsic goals involve behaviours that are viewed as valuable in their own right because they contribute to feelings of personal growth, social connectedness and well-being. As such, they are theorised to provide more complete satisfaction of needs for autonomy, relatedness and competence. In contrast, because extrinsic goals are governed by external incentives such as financial gain, social status and competition, they are believed to have a lower capacity for need satisfaction because they are pursued for reasons external to the self (Deci and Ryan 2000).

Past research on the differential effects of intrinsic and extrinsic goal pursuit supports these theoretical expectations. Studies have shown that intrinsic goals are positively associated with such outcomes as perceived well-being (Schmuck et al. 2000), task involvement (Vansteenkiste et al. 2005) and persistence (Vansteenkiste et al. (2004)). In contrast, extrinsic goals have been linked to lower job and life satisfaction (Vansteenkiste et al. 2007), decreased self-actualisation (Kasser and Ahuvia 2002), high-risk behaviours among adolescents (Williams et al. 2000), depressive symptoms (Niemiec et al. 2009) and greater desire for resource acquisition (Sheldon and McGregor 2000). Goal orientations can tend to be invariant across situations because of people's general tendencies to prefer intrinsic values over extrinsic values or vice versa, but characteristics of the social environment have been shown to influence the types of goals that are adopted in certain situations as well. For instance, among college students, Vansteenkiste et al. (2004) found that learning tasks that were presented in a non-controlling manner as representing a community contribution were positively predictive of deep cognitive processing and academic performance. Similar research has shown that highlighting extrinsic task incentives in academic environments is associated with poorer conceptual learning and decreased autonomous motivation (Vansteenkiste et al. 2005; Vansteenkiste et al. 2008). Such findings have important implications for motivation in the college classroom. Thus far, however, researchers have mainly investigated goal conditions and orientations as predictors of well-being outcomes, with very little attention to intrinsic and extrinsic goals as outcomes in their own right. Moreover, researchers typically examine these environmental effects at the level of the student rather than the classroom. We addressed these issues in the present research by modeling the effects of group-level perceptions of the classroom environment on students' intrinsic and extrinsic goals.

College classroom environment and academic motivation

Perhaps nowhere is self-determined motivation more salient than in the college classroom. College classrooms afford students the opportunity to satisfy their intellectual curiosity, develop competence through successful task engagement and performance, and cultivate relationships that reinforce academic socialisation and development. Indeed, the literature consistently suggests that students learn best in environments that are characterised by collaboration, connectedness and a sense that instructors are genuinely concerned for their welfare (Creasey et al. 2009; Greenfield 2005; Sherman 1986). Accordingly, SDT posits that three contextual factors facilitate satisfaction of needs for autonomy, relatedness and competence. Autonomy support refers to the extent to which authority figures encourage others to choose their problem-solving and decision-making strategies freely, without imposing their own values and exigencies on those over whom they have influence (Deci et al. 1994; Grolnick and Ryan 1989). Environments are thought to promote the internalisation of external regulation to the extent that authority figures' requests for action are presented with a clear rationale and in a non-controlling manner. Structure represents the clarity and consistency of classroom rules, expectations, instructional techniques and feedback practices that aid student learning (Guay et al. 2008; Reeve 2002, 2006). Finally, involvement refers to the extent to which parents and teachers convey to students the importance learning by providing encouragement and support (Ratelle et al. 2007; Reeve 2002).

Classroom environment scholars have conducted research using a dimensional framework (Moos 1974) which closely parallels that of the SDT contextual framework. Examples of classroom environment factors that have been previously studied include task orientation and individualisation (Fraser et al. 1986), instructor warmth and organisation (Freeman et al. 2007), professorial concern (Winston et al. 1994) and course structure (Eddy and Hogan 2014; Winston et al. 1994), and all have been linked to important outcomes such as cheating (Pulvers and Diekhoff 1999), sense of belonging (Freeman et al. 2007) and course performance (Vahala and Winston 1994). However, while a focus on the dynamic interplay between instructors and students in fostering autonomy support is indeed important, interrelations among students themselves have been identified as an area in need of investigation in SDT research (Guay et al. 2008).

Achievement goal theory

Much research shows that motivation in the classroom depends on the types of achievement goals that students pursue (Harackiewicz and Elliot 1993; Church et al. 2001). Achievement goal theory (AGT) posits two fundamental types of aims: those for which people strive to develop competence to self (i.e. mastery) and those for which people strive to demonstrate competence relative to others (Dweck and Leggett 1988; Nicholls 1984). AGT has evolved from this early dichotomous distinction to a more refined, contemporary conceptualisation of the goal types and their sources of competence information (Elliot et al. 2011). That is, one can use the self (i.e. intrapersonal comparison), the task itself, or others as referents in the process of inferring competence. Elliot et al. (2011) integrated this new definitional dimension with the classic approach–avoidance valence dimension (Atkinson 1957; Elliot 1997) to produce six goal types: (a) task-approach goals, which are characterised by an aim to develop absolute mastery of a particular task, (b) self-approach goals, which are characterised by a desire to improve one's skill relative to previous performances on the task, (c) other-approach goals, which represent a desire to perform well relative to others, (d) task-avoidance goals, which are characterised by a desire to avoid failure on a given task, (e) self-avoidance goals, which represent aims to avoid performing badly relative to previous performances and (f) other-avoidance goals, which are characterised by aims to avoid performing poorly relative to others. Self- and task-approach goals in particular bear some conceptual resemblance to intrinsic goals given their shared focus on aims as regulatory mechanisms (Vansteenkiste et al. 2014) and, indeed, there is empirical evidence to suggest that these approach goals are positively associated with task absorption and intrinsic interest (Elliot et al. 2011; Mascret et al. 2015). Research has substantiated the complementary relationship between achievement goals and SDT motives and conditions, but these studies have focused on SDT relations with classical conceptualisations of achievement goals, particular mastery-based goals (e.g. Barkoukis et al. 2007; Benita et al. 2014; Ciani et al. 2011), whereas studies have yet explore these areas of agreement with the 3 × 2 model. Indeed, research on self- and task-approach goals in general is limited given the infancy of the framework. Thus, a secondary purpose of the present research was to extend Vansteenkiste et al.'s (2014) efforts to integrate the SDT and achievement goal frameworks by examining the utility of these two goal types as potential outcomes of classroom climate effects.

Project overview

Across three studies, we examined the factors that comprise the motivational climate in the college classroom, and used these factors to predict the aims, or 'what', of students' science motivations. Specifically, the hierarchical structure of students' science motivations were examined as we estimated perceptions of college science classrooms as level-2 predictors of intrinsic, extrinsic, self-approach and task-approach goals. Key to accurately assessing these level-2 effects is utilising a measure which provides broad conceptual coverage of the dimensions that are purported to comprise the college classroom climate. To this end, we relied on Winston et al.'s (1994) College Classroom Environment Scales (CCES), which tap dimensions related to the interpersonal (i.e. instructor–student, student–student), cognitive engagement and organisational characteristics of the classroom. Because the CCES has been rarely used over the past 20 years, Study 1 examined its psychometric properties using a diverse sample of students in various biology, physics and chemistry courses. Study 2 used a new sample of students to confirm and refine the measurement results of Study 1, with a focus on how the measurement of motivational climate might differ in variance depending on the gender of the science student. Once the contextual measurement tool was defined, Study 3 aimed to test substantive hypotheses about the hierarchical relationships between the identified classroom factors and the four goal types.

General method

Procedure

Data were collected for this study as part of a larger project (2011–2014) involving four universities representing the southwestern, northwestern, southeastern and midwestern U.S. Main hypotheses from that larger study were tested and reported elsewhere (Deemer et al. 2014; Smith et al. 2015; Smith et al. 2014) and the analyses reported here are tested for the first time. As conditions of inclusion in the study, participants were required to be at least 18 years of age and enrolled in the life or physical sciences (i.e. biology, chemistry and physics). All data were collected using an online survey. Course rosters were obtained from each university's registrar's office and students were subsequently recruited via in-class announcements and email requests for participation. The rosters contained only students' names and university email addresses. An email message containing a description of and link to the survey was delivered to targeted students at the midpoint of each semester. Those who chose to participate were asked to reflect on their perceptions of the science class in which they were enrolled. Physics classes were intentionally oversampled to recruit more women in mathematical science for the study. Thus, if participants reported being concurrently enrolled in more than one science class, they were asked to choose one class on which to report based on the following order of priority: (a) physics; (b) chemistry; and (c) biology. Data for Study 1 were collected from the southeastern university in the spring of 2011, data for Study 2 were collected from the northwestern university in the spring and fall semesters of 2011, and data for Study 3 were collected from the southwestern, northwestern and midwestern universities between 2012 and 2014. Upon submitting their responses, participants were directed to a webpage containing a debriefing statement which explained the purpose of the study. Participants received $10 as compensation for their involvement in the study.

Data analytic strategy

M*plus* 7.3 (Muthén and Muthén 1998–2014) was used to perform all confirmatory factor analytic work. We used the maximum likelihood (ML) estimation method for the latter analyses. Model fit was evaluated using the (a) model Chi square test; (b) comparative fit index (CFI); (c) root mean square error of approximation (RMSEA); and (d) standardised root mean square residual (SRMR). CFI values of greater than 0.90 and SRMR values equal to or less than 0.08 are thought to reflect acceptable model fit (Hu and Bentler 1999). Browne and Cudeck (1993) have suggested that RMSEA values equal to or less than 0.05 indicate good model fit, values ranging from 0.05 to 0.08 indicate acceptable fit, and values greater than 0.08 indicate marginal to poor fit.

Measurement invariance testing was included in the preliminary CFAs to ascertain whether men and women interpreted the CCES items similarly. Invariance testing typically follows a sequence in which equality constraints are placed on model parameters in an increasingly restrictive manner. Several types of measurement invariance have been identified (Horn and McArdle 1992; Meredith 1993): (a) configural invariance, in which models are compared across groups under no parameter constraints; (b) metric invariance, in which factor loading equivalence is assessed; (c) scalar invariance, in which the equivalence of item intercepts is examined; and (d) residual invariance, in which the equivalence of error variances is examined. Tests of more restrictive models can be conducted once a model has been found to be invariant at the less restrictive level. The resulting nested models are then statistically compared using the Chi square difference test. However, because the Chi square test is overly sensitive to sample size (Vandenberg and Lance 2000), additional means of assessing invariance have been recommended. In the present study, we employed Cheung and Rensvold's (2002)'s strategy of using Δ CFI values of ≤ 0.01 as an added method of inferring measurement invariance. The multilevel models were evaluated using restricted maximum likelihood estimation in HLM 7.01 (Raudenbush et al. 1996–2013). CCES scores were aggregrated to the class level and centred at their grand means.

Study 1

Participants

Participants consisted of 146 college students aged from 18 to 46 years ($M = 21.13$, $SD = 4.14$). The sample was well-balanced in terms of gender (71 males, 72 females), although three participants did not indicate their gender. Most participants identified as White (83), followed by Asian/Asian American (27), African American (20), Latino (8) and multiracial (5). Three participants did not report their race/ethnicity. There were 43 seniors, 36 freshmen, 33 juniors, 28 sophomores, 2 graduate students and 1 non-degree student. Three students did not indicate their academic classification. Fifty-eight students were enrolled in physics classes, 47 in chemistry classes, 40 in biology classes and one participant did not identify his/her type of class.

Instrument: perceptions of the classroom environment

The College Classroom Environment Scales (CCES; Winston et al. 1994) were used to assess students' perceptions of the motivational climates of their science laboratory class. The CCES consist of 62 items that are designed to tap six theorised components of the collegiate academic environment: (a) Cathectic Learning Climate, which measures students' enthusiasm to learn, and level of activity and participation in class; (b) Professorial Concern, which measures students' perceptions of the instructor as being personally concerned about them as individuals; (c) Inimical Ambience, which measures perceptions of instructor hostility and competitiveness among students; (d) Academic Rigour, which measures the intellectual challenges of the environment; (e) Affiliation, which assesses the extent to which the learning environment is perceived as being supportive and student centred; and (f) Structure, which assesses students' perceptions of course content as being clear and unambiguous. Item responses are scored on a Likert scale ranging from 1 (never or almost never true) to 5 (always or almost always true). Internal consistency estimates range from 0.73 to 0.91 across the subscales and test–retest reliability has been shown to range from 0.81 to 0.88 (Winston et al. 1994).

Results and discussion: principal components analysis

We first psychometrically examined the tool that was used to measure level-2 perceptions of the laboratory environment. This was accomplished by first conducting a principal components analysis (PCA) on the CCES and then examining its underlying factor structure via confirmatory factor analysis (CFA). We performed a PCA on the CCES because some of the items were judged to be either outdated (e.g. “Students daydream, write letters or read the newspaper during class”) or partially irrelevant to students in courses with applied laboratory components (e.g. “Lectures in this class keep students’ interest”). We thus felt that the number of items in the scale could be reduced with little loss of predictive power.

The correlation matrix was subjected to PCA using an eigenvalue > 1 criterion for component retention. Promax was chosen as the rotation method to allow for correlations among the components. Results of the Kaiser–Meyer–Olkin test (0.86) and Bartlett’s test of sphericity, χ^2 (91) = 784.43, $p < 0.001$, indicated that there was sufficient variation in the data to proceed with the analysis. Items with pattern matrix loadings of less than 0.35 or with cross-loading differences of less than $|0.10|$ were removed from the analysis. Items not meeting this criterion were eliminated in an iterative process until a set of 14 items was obtained. Inspection of the scree plot suggested retaining three components that accounted for 60.94% of the variance in the data. The first component, identified as professorial concern, explained 37.52% of the variance (eigenvalue of 5.25), affiliation explained 14.42% of the variance (eigenvalue of 2.02) and academic rigour explained 9.01% of the variance (eigenvalue of 1.26). Because Cronbach’s alpha reliability was found to be inadequate for academic rigour ($\alpha = 0.60$) given Nunnally’s (1978) recommended cutoff value of 0.70, therefore this component was omitted from further analyses. Component loadings for professorial concern and affiliation exceeded 0.50 and both scales exhibited acceptable internal consistency with alpha coefficients of 0.88 and 0.78, respectively. Loadings, descriptive statistics and internal consistency estimates for the final pool of 11 items are presented in Table 1. A correlation analysis revealed a significant positive relationship between professorial concern and affiliation ($r = 0.43$, $p < 0.001$).

The results of this study suggest that the CCES are best represented by two rather than the six factors originally posited by Winston et al. (1994). The weak loadings observed for cathectic learning climate indicate that the patterns of scores vary considerably within classrooms. This could be attributable to variation in students’ academic interests because science majors could be primed to view class discussions and learning activities as being more engaging than non-science majors. Past research using the CCES has shown that students score significantly more highly on CLC within English classes than laboratory science classes (Vahala and Winston 1994). Therefore it is possible that certain characteristics of these types of science courses (e.g. technical material) might not engender consistent perceptions of enthusiasm for learning. Structure and academic rigour items produced high positive cross-loadings, whereas professorial concern and inimical ambience items yielded high negative cross-loadings, suggesting that the latter two factors might represent opposite poles of a single dimension. Overall, these findings suggest that the classroom environment can be best represented by factors pertaining to the importance of interpersonal dynamics rather than structure and delivery of course content. To further examine the construct validity of professorial concern and affiliation scores, we tested their underlying factor structure and gender invariance with a separate sample of college students.

Table 1 CCES items, factor loadings, and descriptive statistics for CCES items

Item	Loading	
	1	2
Factor 1: professorial concern		
(16) It's very clear what students need to do in order to make good grades in this class	**0.67**	− 0.18
(35) The professor shows a genuine interest in students' performance in this class	**0.78**	0.08
(40) Students feel comfortable approaching the professor with problems they are having with the class	**0.65**	0.12
(51) The professor goes out of her or his way to help students who request it	**0.86**	0.08
(53) The professor seems to be understanding about students' personal problems and concerns	**0.80**	0.10
(56) The professor shows respect for students' opinions and points of view	**0.75**	0.03
(58) Students are encouraged to visit the professor in his or her office	**0.71**	− 0.07
Factor 2: affiliation		
(9) There are people in this class with whom I would like to be friends	0.08	**0.64**
(17) Students often help each other with assignments or in understanding difficult material	0.15	**0.54**
(23) Relationships established among students in this class carry over outside of the classroom	− 0.02	**0.86**
(31) Students in this class have gotten to know each other well	0.04	**0.84**
M	3.71	3.47
SD	0.82	0.76
α	0.88	0.78

Bolded coefficients represent primary factor loadings

$N = 146$

Study 2

Participants

Participants for Study 2 were 269 college students enrolled at a mid-sized university in northwestern U.S. The sample was comprised of 137 women and 125 men; seven participants did not indicate their gender. Age ranged from 18 to 44 years ($M = 20.82$, $SD = 3.04$). The majority of participants identified as White (157), followed by Asian/Asian American (55), Latino (18), multiracial (12), African American (9) some other race/ethnicity (9) and Native American (3). Six participants did not identify a race/ethnicity. This sample was populated largely by sophomore students (80), followed by seniors (62), juniors (61), freshmen (51), 5 graduate students and 1 non-degree student. Nine participants did not indicate their academic classification. A total of 112 students were enrolled in a physics class, 90 were enrolled in a chemistry class and 67 were enrolled in a biology class. Research methods were identical to Study 1.

Results and discussion for Study 2

CFAs were conducted to examine the latent structure of CCES scores. We compared the 2-factor model derived in the PCA to the original 3-factor model and an alternative model in which the items comprising the 2-factor model were specified to load onto a single factor. Descriptive analyses were first performed on the 11 items used in the CFAs (see Table 2). There was very little deviation from normality among the scores, supporting the use of normal-theory ML estimation. All indicator regression weights were freely estimated and the variances of the latent factors were fixed to unity to establish a common metric. The 1-factor model was estimated first, followed by the 3- and 2-factor models. Results revealed a poor fit to the data for the 1-factor model, χ^2 (77, $N = 0$ 268) $= 0$ 333.21, $p < 0.001$, CFI = 0.77, RMSEA = 0.11 (90% CI 0.10, 0.12), SRMR = 0.09. Standardised factor loadings ranged from − 0.02 to 0.74, with the weakest loadings being for the items originally posited to load on Academic Rigor in the 3-factor model. The 3-factor model offered an improvement over the 1-factor model, but nevertheless yielded a mediocre fit to the data, χ^2 (87, $N = 0$ 268) $= 0$ 203.48, $p < 0.001$, CFI = 0.90, RMSEA = 0.07 (90% CI 0.06, 0.08), SRMR = 0.09. In contrast, the 2-factor model was found to provide a good fit to the data, χ^2 (43, $N = 0$ 268) = 76.06, $p = 0.001$, CFI = 0.97, RMSEA = 0.05 (90% CI 0.03, 0.07), SRMR = 0.05, with standardised factor loadings ranging from 0.55 to 0.76 (see Table 3). To estimate composite reliabilities for the two factors, we computed coefficient omega (ω), which represents the proportion of variance accounted for by the standardised factor loadings relative to the total variance explained by the factor (McDonald 1978). Reliability coefficients for professorial concern ($\omega = 0.86$) and affiliation ($\omega = 0.73$) were found to be acceptable.

Next, we fitted the 2-factor model separately for men and women. Results indicated a good fit to the data for men, χ^2 (43, $N = 0$ 125) $= 0$ 62.90, $p = 0.025$, CFI = 0.96, RMSEA = 0.061 (90% CI 0.022, 0.092), SRMR = 0.061. Standardised factor loadings ranged from 0.56 to 0.78 with a robust positive relationship being observed between professorial concern and affiliation ($r = 0.61$). The model for women provided a better fit, χ^2 (43, $N = 0$ 137) = 50.19, $p = 0.210$, CFI = 0.98, RMSEA = 0.035 (90% CI 0.000, 0.007), SRMR = 0.055. Standardised factor loadings ranged from 0.49 to 0.76 while the correlation between professorial concern and affiliation was less robust ($r = 0.35$). As can be seen in Table 4, the configural model fits the data well and there was a nonsignificant decrease in fit when equality constraints were placed on the factor loadings, $\Delta\ \chi^2$ (9) = 11.53, *ns*, indicating that the relations of the CCES items to their underlying factors were consistent across gender. A significant increase in the Chi square statistic was

Table 2 Descriptive statistics for items subjected to CFA

Item	*M*	*SD*	Skewness	Kurtosis
Item 16	4.21	0.71	− 0.84	− 0.05
Item 35	3.89	1.04	− 0.66	− 0.23
Item 40	3.92	1.17	− 0.81	− 0.14
Item 51	3.81	1.09	− 0.70	0.01
Item 53	3.40	1.15	− 0.30	− 0.50
Item 56	3.96	0.83	− 0.55	− 0.39
Item 58	3.83	1.14	− 0.66	− 0.30
Item 9	3.65	0.92	− 0.40	− 0.13
Item 17	3.90	0.85	− 0.70	0.17
Item 23	3.32	0.75	− 0.17	− 0.26
Item 31	2.98	0.92	− 0.06	− 0.31

Table 3 CCES standardised factor loadings and 90% confidence intervals

Item	Loading		90% CI
	Professorial concern	Affiliation	
Item 16	0.55		(0.47, 0.62)
Item 35	0.75		(0.70, 0.81)
Item 40	0.69		(0.63, 0.75)
Item 51	0.72		(0.67, 0.78)
Item 53	0.68		(0.61, 0.74)
Item 56	0.76		(0.70, 0.81)
Item 58	0.66		(0.59, 0.72)
Item 9		0.59	(0.50, 0.67)
Item 17		0.59	(0.50, 0.68)
Item 23		0.73	(0.66, 0.81)
Item 31		0.63	(0.55, 0.71)

Table 4 Model fit statistics for tests of measurement invariance across gender

Model	χ^2	*df*	RMSEA (90% CI)	SRMR	CFI	$\Delta\ \chi^2$	Δ *df*	Δ CFI
Configural invariance	113.09	86	0.049 (0.018, 0.072)	0.058	0.971	–	–	–
Metric invariance	124.63	95	0.049 (0.019, 0.071)	0.076	0.968	11.53	9	0.003
Scalar invariance	146.03	104	0.056 (0.032, 0.076)	0.088	0.954	**21.40**	9	0.007

Bolded value indicates significance at $p < 0.05$

observed in the scalar invariance step, $\Delta\ \chi^2\ (9) = 21.40, p < 0.05$. However, this finding is tempered by a negligible Δ CFI value of $-\ 0.007$.

The results of Study 2 largely were consistent with those obtained in Study 1 in that 2-factor model consisting of professorial concern and affiliation was found to outperform 1- and 3-factor models. Affiliation scores were shown to be less reliable than those for professorial concern, but were nevertheless statistically acceptable. Perhaps consistency with respect to perceptions of affiliation was more difficult to attain given that these items ask participants to assess relations among all students in class, whereas professorial concern refers to just one assessment target. Taken together, the current results can be interpreted as supporting the invariance and reliability of the 2-factor CCES model.

Having identified two distinct classroom environment constructs, in Study 3, we examined whether they were predictive of intrinsic, extrinsic and approach-based goals. Professorial concern reflects an environmental dimension in which the professor is perceived by students as being caring, supportive and open to their ideas. We contend that this type of approach is conceptually consistent with an autonomy-supportive instructional style because it allows students to feel they have something valuable to contribute to the group, which in turn should satisfy needs for competence and relatedness. Because professorial concern also implies that such support is offered unconditionally and with the aim of promoting independent thought, this approach should also foster the satisfaction of autonomy needs. Affiliation should also lend itself to the satisfaction of SDT needs to the extent that it facilitates social cohesion, interpersonal learning (contributing to competence development) and greater interest in course material. Thus, we advanced three hypotheses.

Hypothesis 1 Given the affordances conceived above, professorial concern will be a significant positive predictor of intrinsic science motivation, self-approach goals and task-approach goals.

Hypothesis 2 Affiliation will be a significant positive predictor of intrinsic science motivation, self-approach goals and task-approach goals.

Hypothesis 3 Because students might view professorial concern as being instrumental in their attainment of desired course outcomes (e.g. high grade), we predicted that this construct would be a significant positive predictor of extrinsic science motivation.

No hypotheses were advanced with respect to the relationship between affiliation and extrinsic science motivation because satisfaction of relatedness needs is not theorised to give rise to an external regulatory style in SDT.

Study 3

Participants

The sample for Study 3 consisted of 1924 college students enrolled at three U.S. universities. Most participants identified as female (1117 females; 806 males) and one participant did not indicate his/her gender. Age ranged from 18 to 64 years ($M = 20.02$, $SD = 2.64$). Reported ethnicities were White (1441), Asian/Asian American (264), Latino (69), multiracial (54), African American (44), other (24), Arab American (12) and Native American (12). Four participants did not report their race/ethnicity. The majority of participants were enrolled in biology classes (749), followed by physics (629) and chemistry (546). Six hundred twenty-one participants were sophomores, 612 were freshmen, 376 were juniors, 269 were seniors, 9 were graduate students and 36 were non-degree students. One participant did not indicate an academic classification. A total of 368 cases with missing data were removed from the data set using listwise deletion, resulting in a final N of 1556.

Instruments

Academic achievement goals

We used the 3 × 2 Achievement Goal Questionnaire (AGQ; Elliot et al. 2011) to measure approach achievement goals in the present study. The AGQ consists of 18 items that measure six goal constructs (3 items each). Participants respond to the question "How true is this goal statement of you?" on a 7-point Likert-type scale ranging from 1 (*not true of me*) to 7 (*extremely true of me*). The six constructs are (a) task-approach (e.g. "To get a lot of questions right on the exams in this class") (b) task-avoidance (e.g. "To avoid incorrect answers on the exams in this class"), (c) self-approach (e.g. "To perform better on the exams in this class than I have done in the past on these types of exams"), (d) self-avoidance (e.g. "To avoid doing worse on the exams in this class than I normally do on these types of exams"), (e) other-approach (e.g. "To outperform other students on the exams in this class") and (f) other-avoidance (e.g. "To avoid doing worse than other students on the exams in this class”). Evidence of the construct validity of the six goal constructs has been shown through empirical linkages of the goals to approach- and avoidance-based temperaments (Elliot et al. 2011). In terms of internal consistency reliability, Elliot et al. (2011) reported alpha coefficients of 0.88 for task-approach goals, 0.86 for task-avoidance goals, 0.83 for self-approach goals, 0.87 for self-avoidance goals, 0.92 for other-approach goals and 0.91 for other-avoidance goals.

Science motivation

The two science motivation constructs were measured using the Intrinsically Motivated Science Learning (IMSL; 5 items) and Extrinsically Motivated Science Learning (EMSL; 5 items) subscales of the Science Motivation Questionnaire (SMQ; Glynn and Koballa 2006). IMSL measures interest in and enjoyment of science (e.g. “I like science that challenges me”) while EMSL (e.g. “I think about how learning the science can help my career”) taps the influence of prospective outcomes (e.g. grades) on science motivation. Items are scored on a frequency scale ranging from 1 (*never*) to 5 (*always*). The four remaining subscales include (a) Relevance of Learning Science, (b) Responsibility for Learning Science, (c) Confidence Learning Science and (d) Anxiety about Science Assessment. Previous research supports the internal consistency of IMSL scores ($\alpha = 0.83$; Deemer 2015), but little research has been conducted on the EMSL construct. Glynn et al. (2009) dichotomised EMSL by forming career motivation and grade motivation scales but, because the resulting alpha coefficient for the latter construct was low ($\alpha = 0.55$), we utilised the original unitary construct for the present study.

Control variables

We considered the possibility that advanced students might have been more motivated to master the course material than younger students due to developmental factors such as maturity and proximity to career entry. Therefore we controlled for year in school as a level-1 variable. For similar reasons, because STEM majors were likely to be more invested in their science courses than non-STEM majors, major type was also controlled for at level-1 as a dummy-coded predictor. Because we were primarily interested in understanding motivation patterns among students in the life and physical sciences, STEM majors were operationally defined as disciplines representing biology, chemistry and physics and assigned a code of 1. Non-STEM majors were classified as representing all other disciplines (e.g. humanities, education, social sciences) and assigned a code of 0.

Results and discussion for Study 3

Prior to conducting the multilevel regression analyses conditional models were fitted to the data to compute intraclass correlations (ICC) and reliability coefficients for the random level-1 intercepts. These reliability coefficients along with means, standard deviations and alpha reliability coefficients are reported in Table 5. ICC values were 0.112 for intrinsic motivation, 0.073 for extrinsic motivation, 0.025 for task-approach goals and 0.031 for self-approach goals. Although the ICC values for task- and self-approach goals were somewhat low, statistical bases for multilevel modeling decisions can be misleading (Nezlek 2008). Therefore we proceeded with the analysis on the grounds that students’ course-specific achievement goals in the present study were truly nested within the

Table 5 Descriptive statistics for level-1 and level-2 variables

Variable	*M*	*SD*	Range	Reliability (α/B_0)
Level 1				
Task-approach goals	17.41	3.04	3–21	0.85/0.20
Self-approach goals	17.32	3.33	3–21	0.92/0.20
Intrinsic science goals	19.53	3.53	5–25	0.84/0.47
Extrinsic science goals	20.97	3.06	5–25	0.70/0.38
Level 2				
Affiliation	13.99	1.87	7–20	–
Professorial concern	27.55	3.31	16–35	–

α, Cronbach's alpha coefficient; B_0, reliability estimate for random level-1 intercept

classroom climate. A total of 149 classrooms were sampled, and thus the mean cluster size was 10.44. The general model was defined as

$$\begin{aligned} Y_{ij} &= \beta_{0j} + \beta_{1j}(\mathrm{Year}_{ij)} + \beta_{2j}(\mathrm{Major}_{ij}) + r_{ij} \\ \beta_{0j} &= \gamma_{00} + \gamma_{01}\,(\mathrm{Professorial\ Concern}_j) + \gamma_{02}(\mathrm{Affiliation}_j) + u_{0j} \\ \beta_{1j} &= \gamma_{10} \\ \beta_{2j} &= \gamma_{20} \end{aligned}$$

The level-1 intercept was allowed to vary randomly across classes as a function of the level-2 climate predictors and year in school and major were estimated as fixed effects.

Results of the multilevel regression analysis indicated that professorial concern and affiliation were significant positive predictors of intrinsic science motivation (see Table 6). These findings thus suggest that collective perceptions of instructor openness and sensitivity are associated with students' experiences of science as being interesting, enjoyable and worthy of pursuing as an end in itself. A significant positive slope coefficient for affiliation can be similarly interpreted as suggesting that perceptions of a positive social atmosphere in the classroom are also associated with greater intrinsic science motivation. There was a significant main effect of major as a one unit increase from non-STEM to STEM major was associated with an increase of 1.62 units of intrinsic science motivation. Year in school, however, was not related to intrinsic science motivation ($\gamma_{10} = 0.10$, $p = 0.228$). Results for extrinsic science motivation are presented in Table 7. Consistent with our expectations, there was a significant main effect of professorial concern

Table 6 Results of multilevel regression analysis predicting intrinsic science goals

Fixed effects	*Coefficient*	*SE*	*t*	*p*
Grand mean intercept (γ_{00})	19.69	0.13	153.17	< 0.001
Professorial Concern (γ_{01})	0.16	0.06	2.61	0.010
Affiliation (γ_{02})	0.23	0.10	2.28	0.024
Year (γ_{10})	0.10	0.08	1.21	0.228
Major type (γ_{20})	1.62	0.21	7.69	< 0.001
Random effects	**Variance component**	***SD***	**χ^2**	***p***
ISG intercept (u_{0j})	0.69	0.83	219.63	< 0.001
Model deviance = 7402.70				

ISG, Intrinsic science goals

Table 7 Results of multilevel regression analysis predicting extrinsic science goals

Fixed effects	*Coefficient*	*SE*	*t*	*p*
Grand mean intercept (γ_{00})	21.08	0.12	182.17	< 0.001
Professorial concern (γ_{01})	0.13	0.05	2.53	0.012
Affiliation (γ_{02})	0.05	0.10	0.50	0.616
Year (γ_{10})	− 0.11	0.08	− 1.34	0.181
Major type (γ_{20})	0.19	0.18	1.02	0.307
Random effects	**Variance component**	***SD***	**χ^2**	***p***
ESG intercept (u_{0j})	0.72	0.85	257.93	< 0.001
Model deviance = 7026.67				

ESG, Extrinsic science goals

($\gamma_{01} = 0.13$, $p = 0.012$), but affiliation was a null predictor of extrinsic science motivation. Thus, students who perceived their instructors as being personally concerned about them were more likely to be motivated to use course performance as an instrument for academic and career-related gain. Effects of both year in school and major type were nonsignificant.

Our hypotheses for the prediction of task- and self-approach goals were partially supported. As Table 8 indicates, professorial concern was positively and significantly associated with the adoption of task-approach goals ($\gamma_{01} = 0.11$, $p = 0.004$), thus suggesting that students' perceptions that their instructors cared about their development was associated with greater motivation to perform well on examinations and other class-related assignments. The relationship between affiliation and task-approach goals approached significance ($\gamma_{02} = 0.16$, $p = 0.072$) but did not surpass the $p < 0.05$ threshold, thus failing to support our hypothesis. Results for the prediction of self-approach goals are presented in Table 9. As hypothesised, both professorial concern ($\gamma_{01} = 0.11$, $p = 0.005$) and affiliation ($\gamma_{02} = 0.25$, $p = 0.006$) were significant positive predictors of this goal type. Although no specific a priori hypotheses were put forth with respect to year in school, this predictor was negatively related to the adoption of self-approach goals ($\gamma_{10} = -0.17$, $p = 0.025$), thus suggesting that advanced students were less likely than their younger counterparts to strive for the development of science skill.

Table 8 Results of multilevel regression analysis predicting task-approach goals

Fixed effects	*Coefficient*	*SE*	*t*	*p*
Grand mean intercept (γ_{00})	17.57	0.08	209.42	< 0.001
Professorial concern (γ_{01})	0.11	0.04	2.96	0.004
Affiliation (γ_{02})	0.16	0.09	1.81	0.072
Year (γ_{10})	− 0.05	0.07	− 0.75	0.452
Major type (γ_{20})	− 0.20	0.15	− 1.29	0.197
Random effects	**Variance component**	***SD***	**χ^2**	***p***
TAPP intercept (u_{0j})	0.11	0.33	161.91	0.121
Model deviance = 7010.00				

TAPP, Task-approach goals

Table 9 Results of multilevel regression analysis predicting self-approach goals

Fixed effects	*Coefficient*	*SE*	*t*	*p*
Grand mean intercept (γ_{00})	17.43	0.10	167.64	< 0.001
Professorial concern (γ_{01})	0.11	0.04	2.84	0.005
Affiliation (γ_{02})	0.25	0.09	2.79	0.006
Year (γ_{10})	− 0.17	0.08	− 2.24	0.025
Major type (γ_{20})	− 0.17	0.20	− 0.83	0.406
Random effects	**Variance component**	***SD***	**χ^2**	***p***
SAPP intercept (u_{0j})	0.32	0.57	184.17	0.010
Model deviance = 7311.40				

SAPP, Self-approach goals

Findings from this study were largely consistent with the hypothesised patterns of association in that the two classroom climate variables were significant positive predictors of intrinsic science motivation and differentially associated with extrinsic science motivation. They were also predictive of both types of approach goals with the exception of affiliation, which did not predict task-approach goal adoption as anticipated. This finding could be related to the fact that the task-approach goal intercept did not vary significantly across classrooms; thus, it is possible that there was not enough variance to be explained after partialing out the effect of professorial concern. On the other hand, this finding could be attributed to insufficient statistical power as the effect of affiliation nearly met the significance threshold. Overall, these results suggest that the classroom climate plays an important role in fostering the development of internally- and externally-regulated motivation.

General discussion

Self-determination theory proposes that certain conditions within social contexts need to be in place in order for optimal motivation to emerge. The literature suggests that autonomy-supportive academic environments foster greater intrinsic motivation for science (Black and Deci 2000; Lavigne et al. 2007), but no research to date has examined the nature of students' intrinsic and extrinsic science goals as outcomes nested within college science classrooms. The present research addressed this issue by exploring areas of overlap between these goals and self- and task-approach goals using the achievement goal framework (Elliot et al. 2011). Across three studies we refined and tested a measure of classroom climate and examined whether the resulting constructs were meaningfully related to the aforementioned goals. Our hypotheses were generally supported in that perceptions of affiliation and concern by professors were positively associated with adaptive forms of regulation, both at domain- and task-related levels of specificity.

Of the 6 original subscales of the CCES, only professorial concern and affiliation emerged as distinct constructs in studies 1 and 2. The CCES lacks a simple structure in that the items either cross-loaded on academic rigour or did not meet the minimum loading threshold. Interestingly, one of the structure items (i.e. "It's very clear what students need to do in order to make good grades in this class") loaded on professorial concern in both the PCA and CFA, suggesting that having clear expectations for the course in terms of assignments, deadlines, etc. can be interpreted by students as a demonstration by the professor that he/she is genuinely concerned about students' welfare and performance. At first glance, it could seem as if imposing external constraints on behaviour would thwart intrinsic motivation, but research suggests they do not as long as they are presented in a noncontrolling way (Koestner et al. 1984). When contingencies are presented in this manner they can actually promote competence-striving within the framework of the academic environment (Niemiec and Ryan 2009).

As predicted, professorial concern was significantly and positively associated with intrinsic science goals. This suggests that students who sought to find enjoyment and satisfaction in learning science were in classrooms in which professors tended to be perceived as being sensitive to the academic needs of the students. Although we did not directly measure the extent to which students perceived their professors as utilising an autonomy-supportive approach to instruction, this finding contributes to our understanding of other instructor-based attitudes and behaviours that have similar effects on student motivation. Similarly, affiliation was found to be a significant positive predictor of intrinsic science goals. This is consistent with findings highlighting the influence of affiliative environments on intrinsic regulatory styles (e.g. Hassandra et al. 2003) and values (e.g. Kasser et al. 1995). Much of the research on environmental characteristics that promote the adoption of autonomous regulatory styles has focused on the instructor as the salient figure in facilitating this process (Reeve and Jang 2006; Rogat et al. 2014; Roth and Weinstock 2013). The current findings with respect to affiliation contribute uniquely to the SDT literature by demonstrating that student–student relations are equally important in creating an optimal motivational climate. The hypothesis that professorial concern would be positively associated with extrinsic science goals was also supported. Although professors can stimulate intrinsic interest and enthusiasm for learning, their efforts can also be viewed as serving an instrumental purpose of helping students reach any materialistic goals (e.g. prestige, status, wealth) that they might have. The differential relations of professorial concern to the two types of goals can vary as a function of one's causality orientation (Wang et al. 2009). Students who tend to regulate their behaviour on the basis of internal cues might view their professors' supportiveness as fostering their personal growth, whereas those who tend to be externally-oriented might take the perspective that yielding control of their academic development to their professors is the approach that is most conducive to achieving their extrinsic goals. Future research into the extent to which causality orientation moderates the relationship between classroom environment factors and the types of goals that students adopt would be useful.

As predicted, both professorial concern and affiliation were positive predictors of self-approach goals. It would be reasonable to anticipate that STEM majors would be more concerned about developing science competence relative to non-STEM majors, but our results indicated there was no difference between the two major types in this outcome. Interpersonal elements of the classroom environment therefore appear to exert similar effects on motivation for students regardless of their academic/career intentions. It is interesting to note that year in school was a negative predictor of self-approach goal adoption, indicating that older students were less motivated to improve their science skills than their younger counterparts. Supportive and socially dynamic classroom environments thus could play a particularly important role in motivating advanced students who might be losing their desire to excel in their studies. Our hypotheses regarding task-approach goals were only partially supported in that professorial concern was positively related to the outcome but affiliation was not. Perceived support from course instructors was clearly associated with greater motivation to master specific course-related tasks, but social cohesion among students does not appear to have the same effect. One possible explanation for this finding is that self-approach goals can better facilitate actualising tendencies towards personal growth and well-being because they are broadly concerned with learning, improvement and development. In other words, they direct the learner's focus towards the process of development. Task-approach goals, on the other hand, resemble outcome goals in terms of their emphasis on content and quantity of learning. Given that outcome goals are equally consistent with both of the classic achievement goal types (Grant and Dweck 2003), perhaps that task-approach goals do not regulate the satisfaction of SDT needs as efficiently or as comprehensively as self-approach goals. Research which focuses on the role of the two types of approach goals as mediators of the class environment-need satisfaction relationship would provide a substantive test of this proposition.

Limitations

There are several limitations associated with the present research. First, perceptions of the classroom environment were examined only from the perspective of students. Obtaining instructor ratings would provide evidence of consensual agreement between students and instructors regarding the motivational climate in the classroom. Instructors' ratings of affiliation and 360-degree assessment of professorial concern would provide additional sources of data upon which to base evaluations of the constructs' convergent validity. Second, the degree of between-class variation in the level-1 intercepts for self- and task-approach goals was somewhat below the recommended minimum threshold of 0.05 (Hedges and Hedberg 2007), which raises questions about whether there was sufficient similarity in these motivation scores among students within the same classrooms. However, the fact that we were able to detect significant effects in predicting these outcomes indicates that we had sufficient statistical power to justify the use of multilevel regression. Third, the correlational and cross-sectional nature of the data prevented us from concluding that classroom environment variables exert causal effects on students' goals. Finally, it is possible that the data could have been affected by self-selection bias because students who are particularly interested in issues of science motivation could have been more likely to participate in the study than other students.

Implications for student success

Because our findings can be generalised beyond the college classroom to the broader university environment, they have important implications for student retention and persistence. College classrooms are microcosms of the larger university environment that ultimately function as important points of integration into the university community as a whole. Faculty who express empathy for the needs and concerns of students, and encourage this type of interpersonal connectedness among students, are likely to foster a greater sense of belonging to the university community. This is critical in science courses because they serve as gateway courses to engineering which is a discipline notorious for high student attrition, particularly among women and underrepresented minorities (Brainard and Carlin 1998; National Center for Science and Engineering Statistics 2013; Seymour and Hewitt 1997). Perhaps science instructors who are more attuned to the struggles of science students in their classes will be more likely to communicate their observations to faculty advisors who can intervene before decisions to drop out or transfer to another major are made. Towards this end, it is hoped that our findings contribute to the body of literature supporting the positive association between faculty engagement and student engagement in STEM (Gasiewski et al. 2012; Thoman et al. 2015).

Conclusion

The current research indicates that classroom environments represent an important source of motivation for college students in the sciences. Previous research had indicated that warm and supportive learning environments are associated with greater student motivation and engagement (Birch and Ladd 1997; Reeve et al. 2004; Skinner and Belmont 1993; Wentzel 1997), but the bulk of this literature focused on children and adolescents and did not involve examining the utility of SDT- and achievement-based goals as outcomes. We were surprised to find only two dimensions of the classroom environment emerge as viable predictors of goals given prior evidence of the multidimensionality of the CCES. However, this simply underscores the need to conduct more research on the social, motivational and pedagogical elements of learning contexts that foster optimal motivation. Given the growing need to develop a workforce that meets the global economic, technical and environmental challenges of the future, identifying the conditions that energise science-related interest and behaviour will become increasingly important.

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