The Effects of Instructors' Autonomy Support and Students' Autonomous Motivation on Learning Organic Chemistry: A Self-Determination Theory Perspective

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ABSTRACT: This prospective study applied self-determination theory to investigate the effects of students' course-specific self-regulation and their perceptions of their instructors' autonomy support on adjustment and academic performance in a college-level organic chemistry course. The study revealed that: (1) students' reports of entering the course for relatively autonomous (vs. controlled) reasons predicted higher perceived competence and interest/enjoyment and lower anxiety and grade-focused performance goals during the course, and were related to whether or not the students dropped the course; and (2) students' perceptions of their instructors' autonomy support predicted increases in autonomous self-regulation, perceived competence, and interest/enjoyment, and decreases in anxiety over the semester. The change in autonomous self-regulation in turn predicted students' performance in the course. Further, instructor autonomy support also predicted course performance directly, although differences in the initial level of students' autonomous self-regulation moderated that effect, with autonomy support relating strongly to academic performance for students initially low in autonomous self-regulation but not for students initially high in autonomous self-regulation. © 2000 John Wiley & Sons, Inc. *Sci Ed* **84:**740–756, 2000.

INTRODUCTION

The traditional model of college-level instruction in the natural sciences is organized around the lecture hall. Classroom instruction involves a one-way transfer of information,

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with homework problems being the means of trying to engage students in active learning. The unspoken assumption in the model seems to be that students will "sink or swim," according to their innate ability and motivation. Although not well researched, the consequence of this approach often seems to be a Darwinian "weeding out" of those who appear unqualified for careers in medicine or science.

As an experimental approach to improving college-level science instruction, the National Science Foundation created The Workshop Chemistry Project (Gosser et al., 1996), which consists of faculty, learning specialists, and advanced students at a group of Northeastern colleges and universities attempting to facilitate *active* student learning in chemistry courses by providing small-group mentoring relationships for students. In addition to formal lectures, students attend intensive study groups (i.e., workshops) led by advanced students that are intended to provide opportunities for participatory learning, social support, and group problem solving. The six-to-eight-member workshops meet weekly for an hour and a half per session and differ from typical recitation meetings in that they are aimed at facilitating student involvement rather than just reviewing reading or lecture material.

To accomplish this aim, the small-group instructors are trained to be student-centered and to facilitate group problem solving, peer support, and active engagement with the course material. The goal is for all of the group leaders to be highly student-centered, although there is likely to be considerable variability in the extent to which they are successful in creating student-centered learning climates. Consequently, we believed that an introductory organic chemistry course using this approach would be an ideal setting to investigate the effects of the degree to which instructors are student-centered, as well as the effects of the students' motivation for taking the course, on adjustment and performance in the course. We studied one such course over a four-month semester, using self-determination theory (Deci & Ryan, 1985b) to derive hypotheses.

Self-Determination Theory

Self-determination theory suggests that motivated behaviors vary in the degree to which they are autonomous vs. controlled. Behaviors that are *autonomous* have an internal perceived locus of causality (deCharms, 1968), are experienced as volitional, and are performed out of interest or personal importance. According to Deci and Ryan (1991), autonomous behaviors emanate from one's integrated sense of self. In contrast, *controlled* behaviors have an external perceived locus of causality and are experienced as being pressured by interpersonal or intrapsychic contingencies or demands, such as the feeling that one has to achieve high grades to be a worthy person (Ryan, 1982).

Intrinsically motivated behaviors are the prototype of autonomy. They are undertaken out of interest and sustained by the spontaneous thoughts and feelings that emerge as one performs the activity. In contrast, extrinsically motivated behaviors, which are necessary for accommodating to the social environment, are undertaken and sustained because of a contingency such as the offer of a reward. These behaviors vary in the extent to which they reflect autonomous vs. controlled regulation (Ryan & Connell, 1989). Behaviors that are pressured by external contingencies (e.g., parents making a child study) are considered controlled, but through the process of *internalization* initially external regulations can be transformed into internal regulations. The theory distinguishes between different degrees of internalization however—for example, introjected and identified—and it is only when a person has identified with a regulation and integrated it with his or her sense of self that the perceived locus of causality will be fully internal and the behavior will become autonomous (Deci & Ryan, 1991; Deci, Eghrari, Patrick, & Leone, 1994).

Introjection refers to a *partial* internalization in which external regulations are taken in by the individual but are not accepted as his or her own. Introjection is a particularly interesting form of internalization because it is a process in which a regulation becomes part of a person's psychological make up but not part of the person's coherent sense of self (Deci & Ryan, 1991). Introjected regulations are experienced as internal pressures to behave in some particular way (e.g., "I really have to study and will feel guilty if I don't."). *Identification*, in contrast, refers to a fuller internalization in which the person identifies with the value of a behavior and accepts its regulation as his or her own. Through identification, initially controlled behaviors become more autonomous, and the person experiences a greater sense of choice, less internal conflict, and more responsibility for initiating and maintaining the behavior.

To summarize, behavior is defined as controlled when it is regulated either by external contingencies or introjected demands, and it is autonomous when it is intrinsically motivated or regulated by an identification.

Ryan and Connell (1989) developed an approach to assessing the extent to which individuals are relatively autonomous vs. controlled in performing particular behaviors (e.g., doing homework). Referred to as the Self-Regulation Questionnaire (SRQ), it asks people why they engage in specific behaviors and provides a set of reasons that vary along the autonomy-control continuum. Individuals' ratings of the degree to which each reason is relevant for them can be combined to yield a summary score called the Relative Autonomy Index (RAI). Williams and Deci (1996) adapted the SRQ for university-level learning.

Higher (i.e., more autonomous) RAI scores in educational settings have predicted elementary-school students' school engagement, positive affect, conceptual learning, teacher-rated competence, enjoyment of school, and ability to cope effectively with failure (Grolnick & Ryan, 1987, 1989; Grolnick, Ryan, & Deci, 1991; Miserandino, 1996); high-school and junior-college students' not dropping out of school (Vallerand & Bissonnette, 1992; Vallerand, Fortier, & Guay, 1997); and medical students' perceived competence, internalization of values, and subsequent value-congruent behavior (Williams & Deci, 1996).

The Social Context. Self-determination theory proposes that the interpersonal context influences the extent to which individuals are autonomous vs. controlled. The concept of *autonomy support* (Deci & Ryan, 1985b) means that an individual in a position of authority (e.g., an instructor) takes the other's (e.g., a student's) perspective, acknowledges the other's feelings, and provides the other with pertinent information and opportunities for choice, while minimizing the use of pressures and demands. An autonomy-supportive teacher might, for example, provide students with necessary information while encouraging them to use the information in solving a problem in their own way. In contrast, an authority who is *controlling* pressures others to behave in particular ways, either through coercive or seductive techniques that generally include implicit or explicit rewards or punishments. An example would be a teacher who tells students they have to solve problems in a particular way in order to do well on a test. One can see that being autonomy supportive (rather than controlling) in an educational setting is essentially what is typically meant by being student-centered, so in this research we have instantiated what The Workshop Chemistry Project refers to as student-centered with the concept of autonomy support.

According to self-determination theory, autonomy-supportive contexts tend to maintain or enhance intrinsic motivation and promote identification with external regulations, while controlling contexts tend to undermine intrinsic motivation and forestall internalization. And, indeed, research has found that autonomy-supportive classrooms were associated with more intrinsic motivation (Deci, Schwartz, Sheinman, & Ryan, 1981) and internalization (Grolnick & Ryan, 1989) than were controlling classrooms. Autonomy-supportive parenting has also been related to children being more autonomous in doing their school work (Grolnick, Ryan, & Deci, 1991).

Other research has shown that autonomy-supportive, relative to controlling, social contexts were associated with better conceptual learning (Grolnick & Ryan, 1987), more creativity (Koestner, Ryan, Bernieri, & Holt, 1984), and more positive affect in regular-education (Ryan & Grolnick, 1986) and special-education settings (Deci, Hodges, Pierson, & Tomassone, 1992).

Causality Orientations. Self-determination theory also uses a general individual difference concept referred to as general causality orientations. There are three orientations: the autonomy, controlled, and impersonal orientations, which are assessed with the General Causality Orientations Scale (GCOS) (Deci & Ryan, 1985a). The *autonomy* orientation, which describes the tendency to be autonomous across domains and to orient toward autonomy-supportive aspects of the environment, has correlated positively with ego development, self-esteem, and self-actualization (Deci & Ryan, 1985a) and with personality integration (Koestner, Bernieri, & Zuckerman, 1992). The *controlled* orientation, which describes the tendency to be controlled and to orient toward controlling inputs, has correlated positively with Type A behavior and public self-consciousness (Deci & Ryan, 1985a), and the *impersonal* orientation, which describes the tendency to be unmotivated and to orient toward environmental inputs that promote incompetence, has correlated with social anxiety, depression, and self-derogation (Deci & Ryan, 1985a).

It is expected that the general autonomy orientation will contribute to students' being autonomous in their domain-specific organic-chemistry learning and to their having positive experiences in the course. Further, it is expected that the other two orientations will detract from autonomy and positive affect. Thus, causality orientations were assessed to remove their effects so we could explore the effects of course-specific autonomous motivation.

The Present Study. In this study, we hypothesized that (1) students' taking the organic chemistry course for relatively autonomous reasons, and (2) having leaders who were perceived to be more autonomy-supportive would lead to greater perceived competence and interest/enjoyment for chemistry and to less chemistry-related anxiety and grade orientation. Autonomy-supportive learning climates were also expected to predict students' becoming more autonomous during the course, and both autonomy support and autonomous motivation were expected to predict performance in the course (after controlling for ability). Finally, we expected that students who dropped out of the course during the semester would have started the course with lower relative autonomy for studying organic chemistry than those who stayed in the course.

A study with a design similar to the present one (Williams & Deci, 1996) revealed that instructor autonomy support in a medical interviewing course predicted significant increases in medical students' autonomous motivation (RAI), perceived competence, and valuing of psychosocial medicine. Autonomous motivation also related to the students' using an autonomy-supportive style in interviewing a simulated patient six months later. Support for the present hypotheses would thus extend the results of the Williams and Deci (1996) study to additional adjustment variables and to content learning *per se* (i.e., exam performance).

Two important differences between the studies are worth noting. First, whereas the course content of medical interviewing has some conceptual relation to the construct of "instructor autonomy support," the course content of organic chemistry is orthogonal to instructor style. Second, whereas medical students typically want to learn medical interviewing, some students dread organic chemistry, so there is likely to be considerably more variability in the relative autonomy of students in the present study. Thus, the present course offers an opportunity to explore whether the reactions of students quite high in relative autonomy would be different in kind from the reactions of students quite low in relative autonomy.

METHOD

Participants were students at a small, eastern university taking an introductory organic chemistry course organized in accord with The Workshop Chemistry Project (Gosser et al., 1996) described earlier. They attended standard full-class lectures and were randomly assigned to a study groups (i.e., a workshop) consisting of six to eight members, led by one of 42 different advanced undergraduate or graduate students, that met weekly for two hours. The workshop leaders had received some training in how to facilitate group problem solving, peer support, and active engagement with the material. Participation in the workshops was expected and attendance at the 13 weekly workshops was high (M = 11.8 weeks attended, SD = 1.8, range = 5–13).

Participants completed questionnaires during two of the course's lecture meetings. They were informed that participation was voluntary, would have no bearing on their grade in the course, and involved filling out two sets of questionnaires during the term. Students were also told that their responses would be held completely confidential and that the course professor and workshop instructors would not have access to them. Of the roughly 380 students present at the Time 1 (T1) data collection, 289 completed the questionnaires. Over the term, 41 of the 289 dropped out of the course, and at Time 2 (T2), 162 students provided complete data; however, only 137 of them had also provided complete data at T1, so those 137 comprise the primary sample for the study. The T1 assessment took place during the week prior to the first exam and the T2 assessment occurred during the week after the fourth and last regular exam, but two weeks before the final exam.

To determine whether the students who stayed in the course but did not provide T2 data differed from the students in the study sample, a MANOVA was performed on all T1 variables (perceived leader autonomy support, relative autonomy index, perceived competence, interest/enjoyment, anxiety, grade orientation, and general causality orientations—autonomy, competence, and impersonal, all of which are described in the next section). There was not a significant difference [$F(9,224) = 0.74$]. Further, none of the univariate ANOVAs yielded a significant difference. The two groups do not seem to differ on any of the study variables.

Measures

The General Causality Orientations Scale (GCOS) (Deci & Ryan, 1985a) consists of 12 hypothetical vignettes followed by three ways of responding to the situation—autonomous, controlled, and impersonal. Participants rate on a 7-point scale how likely they would be to respond in each of the three ways. The three subscale scores are calculated by adding the 12 responses for each. Alpha reliabilities for the subscales in the current data were: autonomy (0.79), controlled (0.69), and impersonal (0.75). The GCOS was administered only at T1.

The Learning Climate Questionnaire (LCQ) was adapted by Williams and Deci (1996) from the Health-Care Climate Questionnaire (Williams, Grow, Freedman, Ryan, & Deci, 1996). This 15-item measure asks students questions, answered on Likert scales, about the degree to which their workshop leader supports their autonomy (e.g., "My group leader listens to how I would like to do things"). The LCQ has a single underlying factor with high internal consistency (Williams & Deci, 1996), and the score for leader autonomy support (LAS) is the sum of the 15 items. In the present study, the LCQ had alphas of 0.93 and 0.94 at T1 and T2, respectively.

When the LCQ was administered at T1, students had met with their workshop leaders only one to three times, whereas at T2 they had worked together for nearly a semester. (There was a small increase in perceived autonomy support from T1 to T2, as shown in Table 1, which was likely a function of the students' knowing the workshop leaders better at T2.) We used the average of the T1 and T2 ratings of leaders autonomy support (LAS) as an independent variable in the analyses. This value was expected to be more accurate than the T1 score and to be less problematic than the T2 score in terms of method variance when used to predict changes from T1 to T2 in other variables. The T1 and T2 LAS scores were significantly correlated [$r(136) = 0.50$, $p < .0001$].

The Learning Self-Regulation Questionnaire (LSRQ) was adapted from the original SRQ designed for elementary students (Ryan & Connell, 1989) and the subsequent version adapted for medical students (Williams & Deci, 1996). Participants rated how true each of 12 reasons was for why they were studying organic chemistry, using Likert scales. Four of these reasons were either intrinsic or identified, thus being considered autonomous (e.g., "I will participate actively in organic chemistry because a solid understanding of organic chemistry is important to my intellectual growth"), and eight were either external or introjected and were thus considered controlled (e.g., "I will participate actively in organic chemistry because a good grade in the course will look good on my record"). Subscale scores were the sum of the items on each subscale. T1 subscale alphas were 0.75 for autonomous and 0.67 for controlled. The Relative Autonomy Index (RAI) was calculated by subtracting the *z*-score for the controlled subscale from the *z*-score for the autonomous subscale. Autonomous reasons correlated with the general autonomy orientation of the GCOS [$r(136) = 0.44$, $p < .001$], and controlled reasons correlated with both the controlled orientation and the impersonal orientation of the GCOS [$rs(127) = 0.28$ and 0.34, respectively, both $p < .01$], thus providing some construct validity for this adaptation of the LSRQ.

The Perceived Competence Scale (PC) is a 5-item measure adapted from Williams and

TABLE 1
Descriptive Statistics For, and Comparisons Between, Time 1 and Time 2 Variables ($n = 137$)

Variable	Time 1 Mean	Time 1 SD	Time 2 Mean	Time 2 SD	*t* (T1 vs. T2)
Group Leader Autonomy Support (LAS)	60.7	11.3	62.6	10.9	2.18*
Autonomous Reasons (AR)	14.8	3.6	14.8	3.5	ns
Controlled Reasons (CR)	24.2	5.9	24.4	4.2	ns
Perceived Competence (PC)	19.7	3.6	19.3	4.0	ns
Interest and Enjoyment (I/E)	31.9	7.4	32.1	8.3	ns
State Anxiety (STAI)	33.3	10.9	33.2	11.2	ns
Grade Orientation (GO)	16.4	2.7	15.9	2.6	2.54*

*$p < .05$

Deci (1996). Students rated the truth of five felt-competence items (e.g., “I have confidence in my ability to be successful in organic chemistry”). The total score is the sum of the 5-item ratings. T1 and T2 alphas were 0.86 and 0.90, respectively.

The Interest/Enjoyment (I/E) measure, also adapted from Williams and Deci (1996), asks students to rate the truth of nine statements (e.g., “I enjoy learning about organic chemistry” and “Organic chemistry is a subject I find interesting”). The total score is the sum of the nine items. Principal components analyses revealed a single factor solution. T1 and T2 alphas were 0.86 and 0.90, respectively.

The State-Trait Anxiety Inventory (STAI) (Spielberger, Vagg, Barker, Donham, & Westberry, 1980) measured how much anxiety students felt about organic chemistry. They rated the degree to which 15 statements describe them (e.g., “When it comes to taking organic chemistry I feel nervous”). The total score is the sum of the 15 responses. T1 and T2 alphas for this well-validated measure were 0.95 and 0.96, respectively.

The Grade-Orientation (GO) measure has four items, constructed for this study to index the extent to which students are focused more on grades than on learning. This is closely related to Dweck’s (1986) concept of a performance-goal orientation. Students rated the truth of items such as, “I care much more about what I learn than about the grades I get.” The total GO score is the sum of the four responses, with two of the items reverse scored (including this sample). T1 and T2 alphas were 0.75 and 0.71, respectively.

Adjustment in the course, although not a specific measure, was considered to be reflected in higher scores on perceived competence and interest/enjoyment and lower scores on anxiety and grade-orientation.

Ability. Measures of ability were used as control variables. One was the students’ cumulative grade point average (GPA) prior to the course, obtained from the registrar; and the other was a composite of self-reported scores on the Math and Verbal SATs and self-reported number of advanced placement credits in math and science successfully transferred from high school. This composite was formed by converting each of the indicators to a *z*-score for the sample and combining them. Twenty of the students in the primary sample failed to provide their SATs, so analyses that controlled for ability had a smaller sample size.

Performance. There were two performance measures. *Exams* refers to the average of the first four exam scores, which students had taken when they provided T2 data. This was used in some analyses to control for the effects of grades on the adjustment measures. *Course grade* refers to the final grade received in the course and was one of the primary dependent variables. Both performance scores were obtained from the professor by social security number.

Factor Structure of the Scales. Three principal components factor analyses with varimax rotations were performed on responses from the 289 students who provided T1 data to evaluate the structure of the scales adapted from Williams and Deci (1996). First, the 15 items of the LCQ yielded a single-factor solution (eigenvalue = 7.9) that accounted for 52.7% of the variance. Next, the 12 items from the LSRQ yielded the expected two-factor solution accounting for 40.3% of the variance. Four items (eigenvalue = 2.3) loaded on the autonomous factor and eight items (eigenvalue = 2.5) loaded on the controlled factor, all at 0.45 or above, with no cross loadings above 0.25. Finally, 18 items assessing three of the adjustment variables (interest/enjoyment, perceived competence, and grade orientation) yielded a 3-factor solution that accounted for 63.1% of the variance. Five items (eigenvalue = 2.4) loaded on perceived competence; nine items (eigenvalue = 6.9) loaded on interest/enjoyment; and four items (eigenvalue = 2.0) loaded on grade orientation, all with loadings of 0.60 or above and no cross loadings above 0.29.

RESULTS

Table 1 presents means and standard deviations for T1 and T2 measures, along with *t*-values for T1 to T2 differences. Only two variables, perceived leader autonomy support (LAS) and grade orientation, changed significantly. As mentioned, the increase in LAS likely resulted from the students' getting to know their instructors better. The decrease in grade orientation may have been due to this format for teaching organic chemistry, which was more student-centered than is typical for that course and may have prompted a relatively greater focus on learning than grades.

Table 2 presents correlations among the primary study variables, presented in a way that allows an inspection of the hypothesized relations among leader autonomy support (averaged for T1 and T2), motivation variables at T1 (RAI and the GCOS scores), and adjustment variables at T2 (perceived competence, interest/enjoyment, anxiety, and grade orientation). Most of the expected relations were significant, and all significant relations were in the expected direction. Finally, although not included in the table, gender showed very few relations to other variables so it was not included in further analyses.

In order to test the hypothesis that taking the course for relatively autonomous reasons (RAI at T1) would predict more positive subjective experiences during the course, as reflected in more positive T2 adjustment scores, perceived competence (T2), interest/enjoyment (T2), anxiety (T2), and grade orientation (T2) were each regressed hierarchically onto RAI (T1) after first removing the variance attributable to exam scores (which represented students' grade at the time they completed the T2 adjustment measures) and the three GCOS subscale scores (in order to explore the effect of just the course-specific autonomous motivation). Table 3 shows that, after controlling for the effects of exam performance and causality orientations, relative autonomous motivation for taking the course (T1) significantly predicted better T2 adjustment on all four indicators, as predicted, thus supporting the hypothesis. It is worth noting that all significant relations for the GCOS subscales were in the direction that would be expected from the theory.

To test whether taking the course for relatively autonomous reasons (RAI at T1) would be related to whether the students stayed in or dropped out of the course, we did a one-way ANOVA on the RAI (T1) to compare the two groups. The RAI (T1) mean (*z*-score) for 42 students who dropped the course was −0.39 and for the 254 who did not was 0.03. These were significantly different [$F(1,295) = 4.15$, $p < .05$], thus indicating that students with lower initial RAI scores were more likely to drop out of the course.

The hypotheses that leader autonomy support would predict an increase in students' RAI, as well as better adjustment in the course, were tested by hierarchically regressing each of the five key variables (RAI, perceived competence, interest/enjoyment, anxiety, and grade orientation) at T2 onto the corresponding T1 score (to create change scores) and then onto perceived leader autonomy support. As shown in Table 4, all betas were in the predicted direction and all except GO were significant, thus providing considerable support for this set of hypotheses. Because, as shown in Table 2, students' average exam grades at the point when students provided T2 data were correlated significantly with T2 scores on perceived competence, interest/enjoyment, and anxiety, we repeated the regressions for those three variables, creating change scores and controlling for exams before entering LAS. The change in all three variables attributable to LAS remained significant even after

TABLE 2

Zero-order Correlations Among Key Study Variables Relevant to Testing Hypotheses (n = 137)

	LAS	RAI (T1)	GCOS-A	GCOS-C	GCOS-I	PC (T2)	I/E (T2)	STAI (T2)	GO (T2)	Exams
LAS										
RAI (T1)	0.14									
GCOS-A	0.15	0.30***								
GCOS-C	−0.06	−0.16	0.15							
GCOS-I	−0.17*	−0.31***	−0.16	0.23**						
PC (T2)	0.43***	0.39***	0.09	−0.07	−0.32***					
I/E (T2)	0.28**	0.45***	0.24**	−0.05	−0.11	0.57***				
STAI (T2)	−0.43***	−0.29***	−0.01	0.19*	0.28**	−0.71***	−0.40***			
GO (T2)	−0.11	−0.25**	−0.10	0.21*	0.09	−0.15	−0.15	0.25**		
Exams	0.29**	0.08	−0.06	−0.12	0.06	0.59***	0.44***	−0.49***	−0.07	
Course grade	0.25**	0.05	0.00	−0.07	0.06	0.49***	0.38***	−0.44***	−0.11	0.92***

Notes: T1 = Time 1; T2 = Time 2; LAS = Leader Autonomy Support; RAI = Relative Autonomy Index; GCOS-A = General Causality Orientations Scale—Autonomy; GCOS-C = General Causality Orientations Scale—Control; GCOS-I = General Causality Orientations Scale—Impersonal; PC = Perceived Competence; I/E = Interest and Enjoyment of Chemistry; STAI = State Anxiety about Chemistry; GO = Grade (rather than learning) Orientation; Exams = Performance on first four exams.

* $p < .05$; ** $p < .01$; *** $p < .001$.

TABLE 3
Multiple Regressions Testing the Effects of T1 Relative Autonomy on T2 Adjustment Measures, Controlling for Exam Performance and Causality Orientations (n = 136)

DV =	PC (T2)	I/E (T2)	STAI (T2)	GO (T2)
Degrees of Freedom	(5,130)	(5,130)	(5,130)	(5,130)
Step 1: Exams	0.62***	0.43***	−0.50***	−0.06
GCOS-A	0.04	0.28***	0.00	−0.12
GCOS-C	0.09	−0.04	0.06	0.20*
GCOS-I	−0.37***	−0.09	0.30***	0.02
Step 2: RAI (T1)	0.27***	0.40***	−0.19*	−0.19*
Model R-Sq.	0.54***	0.40***	0.37***	0.08*

Reported are Standardized betas.
Notes: T1 = Time 1; T2 = Time 2; Exams = Performance on first four exams; GCOS-A = General Causality Orientations—Autonomy; GCOS-C = General Causality Orientations—Control; GCOS-I = General Causality Orientations—Impersonal; RAI = Relative Autonomy Index; PC = Perceived Competence; I/E = Interest and Enjoyment of Chemistry; STAI = State Anxiety about Chemistry; GO = Grade Orientation.
*$p < .05$; **$p < .01$; ***$p < .001$.

controlling for exam grades: for perceived competence [$\beta(3,133) = 0.13$, $p < .05$]; for interest/enjoyment [$\beta(3,133) = 0.13$, $p < .05$]; and for anxiety [$\beta(3,133) = -0.23$, $p < .001$].

The next hypotheses to be tested were that perceived leader autonomy support and students' relative autonomy would predict course performance, after controlling for the students' ability. Final grade for the course was regressed onto a composite of the students' SAT scores and advanced placements in math and science and onto cumulative GPA to control for ability, and then onto LAS, RAI (T1), and the interaction of LAS and RAI. As shown in Table 5, after removing the effects of ability, LAS did predict significant variance in course grade [$\beta(5,111) = 0.23$, $p < .01$], thus supporting the hypothesis that leader

TABLE 4
Multiple Regressions Testing the Effects of Perceived Leader Autonomy Support on Changes From T1 to T2 in Relative Autonomous Self-Regulation and Adjustment in the Course (n = 137)

DV =	RAI (T2)	PC (T2)	I/E (T2)	STAI (T2)	GO (T2)
Degrees of Freedom	(2,134)	(2,134)	(2,134)	(2,134)	(2,134)
Corresponding T1 Score	0.59***	0.68***	0.66***	0.59***	0.71***
LAS	0.15*	0.24**	0.17*	−0.32***	−0.12

Reported are Standardized betas.
Note: T1 = Time 1; T2 = Time 2; Corresponding T1 Score = The respective T1 scores for each dependent variable entered to create change score; RAI = Relative Autonomy Index (LSRQ); PC = Perceived Competence; I/E = Interest and Enjoyment of Chemistry; STAI = State Anxiety about Chemistry; GO = Grade Orientation; LAS = Group Leader Autonomy Support.
*$p < .05$; **$p < .01$; ***$p < .001$.

TABLE 5
Multiple Regressions Concerning the Effects of Group Leader Autonomy Support, Students' Relative Autonomy, and Their Interaction on Final Grade for the Course, Controlling for Students' Ability.

	DV = Final Grade for the Course		
	Overall Sample $n = 117$ (SE B)/β	Low Relative Autonomy $n = 62$ (SE B)/β	High Relative Autonomy $n = 55$ (SE B)/β
Degrees of Freedom	(5,111)	(3,58)	(3,51)
Step 1: SATs	(0.03)/0.20*	(0.05)/0.14	(0.04)/0.20
GPA	(0.16)/0.51***	(0.24)/0.44***	(0.21)/0.59***
Step 2: LAS	(0.01)/0.23**	(0.01)/0.44***	(0.01)/0.03
RAI	(0.13)/0.06		
Step 3: LAS × RAI	(0.03)/−1.44*		
Model R-Sq.	(0.67)/0.44**	(0.68)/0.41***	(0.66)/0.45***

Reported are Standardized betas.

Note: SAT = a composite of SAT math and verbal scores and the number of advanced placement math and science credits transferred from high school; GPA is cumulative grade point average at the university; LAS = Leader Autonomy Support; RAI = Relative Autonomy Index.

* $p < .05$; ** $p < .01$; *** $p < .001$.

autonomy support would predict course performance. RAI (T1) did not predict significant variance [$\beta(5,111) = 0.06$, ns] thus failing to support the hypothesis that students' RAI at T1 would predict course performance. However, because LAS had predicted an increase in RAI during the semester, we then explored whether change in RAI would predict grades for the course. We regressed course grades onto the two ability variables and then onto the change in RAI from T1 to T2. The result for change in RAI was significant [$\beta(3,113) = 0.21$, $p < .01$]. Thus, although initial level of autonomous motivation did not predict performance, becoming more autonomous during the semester did lead to higher grades. The interaction of LAS and RAI shown in Table 5 was included to explore whether students who are widely discrepant in their initial autonomous motivation for taking the course would respond differently to the learning climate. The results in Table 5 show that the interaction of LAS and RAI did predict course performance [$\beta(5,111) = -1.44$, $p < .05$].

In order to clarify the interaction, we separated students on the basis of whether their T1 RAI *z*-scores were greater than or less than zero. We then regressed Course Grade onto LAS, after controlling for students' ability. The results, also presented in Table 5, showed clearly that autonomy support was quite strongly related to performance within the group of students who were not autonomously motivated for the course [$\beta(3,58) = 0.44$, $p < .001$], but not within the group of students who were high in autonomous motivation. Providing interpersonal support for students who were not volitional in taking this natural science course seems to have been quite important for them to do well in the course, although students who were autonomously motivated did not seem to need the instructor support in order to do well.

Given that the autonomy supportiveness of the workshop leader had different effects on the performance of students high vs. low on the RAI, we explored whether RAI would also moderate the effects of LAS on changes in the adjustment variables. Separately for the high and the low RAI students, we regressed each of the four adjustment variables at T2 onto the corresponding T1 scores and then onto LAS. Results presented in Table 6 show slightly different patterns of effects for the students high vs. low in initial RAI, but LAS did relate to change in three out of the four affect variables for each group of students. Students relatively high in autonomy when they began the course became better adjusted during the course, as reflected in perceived competence, anxiety, and grade orientation: for perceived competence [$\beta(2,54) = 0.33$, $p < .01$]; for anxiety [$\beta(2,54) = -0.43$, $p < .001$]; and for grade orientation [$\beta(2,54) = -0.26$, $p < .05$]. Further, students relatively low in initial autonomy also became better adjusted during the course, as reflected in perceived competence, interest/enjoyment, and anxiety: for perceived competence [$\beta(2,66) = 0.21$, $p < .05$]; for interest/enjoyment [$\beta(2,66) = 0.30$, $p < .01$]; and for anxiety [$\beta(2,66) = -0.31$, $p < .01$]. Thus, although the effects were somewhat different, the results indicate that autonomy-supportive learning climates have a positive relation to the adjustment of students both high and low in initial autonomous motivation.

DISCUSSION

There were three major thrusts to the findings of this study that related the motivation variables of students' relative autonomy and perceived leader autonomy support to adjustment and performance in an organic chemistry course. We consider these in turn.

First, as predicted, when students entered the course with more autonomous motivation, they had more positive experiences in the course, as indexed by higher perceived competence and interest/enjoyment and by lower anxiety and grade orientation at the end of the course. These findings emerged after we controlled for the effects of exam grades and general causality orientations so the effects could be directly attributed to the relative autonomy of course-specific motivation. Further, the data confirmed the hypothesis that students' initial level of relative autonomy would relate to staying in vs. dropping out of the course. Being relatively autonomously motivated when entering the course seems to have been important for staying in the course as well as adjusting to it. The data failed to support our prediction that students' initial level of relative autonomous motivation would relate directly to performance in the course, but change in students' relative autonomous motivation during the semester did predict course performance. Those students who became more autonomous received better grades in the course.

The results relating relative autonomy to adjustment variables are consistent with the findings of the Williams and Deci (1996) study, as well as other studies (e.g., Grolnick & Ryan, 1989; Ryan & Connell, 1989). Furthermore, the results relating relative autonomy to staying in the course are consistent with the results of studies by Vallerand and colleagues (Vallerand & Bissonnette, 1992; Vallerand, Fortier, & Guay, 1997).

It is difficult to know why initial relative autonomy did not relate directly to course learning in this study. Perhaps it is because of the unique nature of the course. This course has great instrumental importance for medical-school and graduate-school admissions, so doing well in this course has greater significance than doing well in most other courses. Thus, the reaction of students in this course who were relatively controlled may have been different from the typical reactions of students who are relatively controlled. Whereas it is generally the case that students whose motivation is controlled tend to be disaffected, exerting little effort, feeling anxious, and doing badly, in this course, students whose motivation was relatively controlled may have put a great deal of extra pressure on themselves because of the course's instrumental importance. If so, then, even though the controlled students in this course felt anxious and did not enjoy the course, the extra pressure

TABLE 6

Multiple Regressions Testing the Effects of Perceived Leader Autonomy Support on Changes in Adjustment for Students with High Initial Relative Autonomy (*n* = 57) and Students with Low Initial Relative Autonomy (*n* = 69).

	PC (T2)		I/E (T2)		STAI (T2)		GO (T2)	
DV =	High RAI	Low RAI	High RAI	Low RAI	High RAI	Low RAI	High RAI	Low RAI
Degrees of Freedom	(2,54)	(2,66)	(2,54)	(2,66)	(2,54)	(2,66)	(2,54)	(2,66)
Step 1: Time 1 Score	0.44***	0.61***	0.68***	0.57***	0.52***	0.54***	0.76***	0.63***
Step 2: LAS	0.33**	0.21*	0.06	0.30**	−0.43***	−0.31**	−0.26*	0.02

Reported are Standardized betas.

Note: T1 = Time 1; T2 = Time 2; Time 1 Score = The respective T1 scores for each dependent variable; LAS = Leader Autonomy Support; PC = Perceived Competence; I/E = Interest and Enjoyment of Chemistry; STAI = State Anxiety about Chemistry; GO = Grade Orientation.

* $p < .05$; ** $p < .01$; *** $p < .001$.

they put on themselves may have overcome the negative performance effects usually associated with controlled motivation. This interpretation is consistent with the widely used expectancy-valence approach to achievement behavior, which does not distinguish between autonomous and controlled motivation. From that perspective, motivation and performance are a function of the value of an outcome (e.g., getting into medical school) and the instrumentality of a behavior (e.g., doing well in organic chemistry) for attaining the outcome. Perhaps when the value is great enough and the instrumentality clear enough, the amount of resulting motivation overrides the significance of the type of motivation in predicting performance. Additional research will be necessary to explore this further.

The second set of results, as predicted, is that students' perceptions of leader autonomy support explained significant increases over the semester in the relative autonomy of students' self-regulation for studying organic chemistry. Also, as predicted, students' perceptions of workshop leader autonomy support explained enhanced adjustment as indicated by significant increases in perceived competence and interest/enjoyment and a significant decrease in anxiety during the semester. These relations held even when the variance attributable to course grade was removed from the adjustment indicators. Furthermore, and perhaps most interestingly, the students' perceptions of workshop leader autonomy support accounted for significant variance in course performance, over and above the variance explained by the students' abilities. Students who perceived their leaders as more autonomy supportive performed better in the course.

An alternative interpretation to the finding of leader autonomy support leading to better performance is that students' doing well in the course led them to have positive perceptions of their workshop leader and of themselves. Although we do not have a definitive test of this alternative interpretation, there are two findings that argue against it. First, the fact that perceptions of the autonomy support of the leader led to positive adjustment after the effects of course grade had been removed from adjustment indicators suggests that covariance in the perception variables is not caused by how well students were doing in the course. Second, we averaged across the perceived autonomy support of the leaders within each workshop group and found that that correlated significantly with the average course grade for the students in that group [$r(41) = 0.19$; $p < .05$]. Because students were randomly assigned to the 42 workshop groups, there is no reason why students in one group would have done better than those in another group other than that the group leader affected their performance.

The results relating autonomy support to autonomous self-regulation, adjustment, and learning are consistent with and extend the results of previous studies. Autonomy support has been shown to lead to greater autonomous motivation in students (e.g., Grolnick & Ryan, 1989; Williams & Deci, 1996) and to have substantial advantages in terms of students' experience and adjustment (see Ryan & Stiller, 1992, for a review). Autonomy support has also been related to learning in experiments with elementary and college students (e.g., Benware & Deci, 1984; Grolnick & Ryan, 1987). The present results are important in that they are the first to focus on a college-level natural science course, and they are the first to link instructor autonomy support to actual exam performance in an ongoing educational setting.

The third set of results concerns the interaction between students' initial level of relative autonomy for taking the course and their perceptions of the leader autonomy support that had a significant effect on course performance. Specifically, students' initial level of relative autonomy moderated the effects of instructor autonomy support on performance, such that students low in relative autonomy at the beginning of the course performed significantly better if they perceived their leaders as more autonomy supportive, whereas the performance of students high in relative autonomy at the beginning of the course was not affected by their perceptions of the leaders' autonomy support. It seems that students who were not autonomously motivated needed the leaders' interpersonal support in order to do well in the course, but that students who were autonomously motivated did not need the leaders' support to perform well.

The moderating effect of relative autonomy in the relation of autonomy support to performance has not appeared in previous studies, which have instead found an overall positive relation between autonomy support and conceptual learning. It is, however, particularly important to note that it was the students' low in autonomous self-regulation whose performance benefited from autonomy support, because instructors faced with such students may be inclined to become more controlling as a way of trying to motivate them. The results show clearly, however, that just the opposite is what these students need if they are to perform well in the course.

In contrast to the performance results, students' initial RAI did not, in general, moderate the effects of leader autonomy support on the adjustment variables. LAS predicted increases in perceived competence and decreases in anxiety for students both high and low in initial autonomous motivation. The only difference between the two groups was that LAS predicted a decrease in grade orientation for students high in RAI but not for students low in RAI, whereas it predicted an increase in interest/enjoyment for students low in RAI but not for students high in RAI. In general, then, although initial RAI scores did have some moderating effects on adjustment variables, the general pattern indicates that supporting the autonomy of students both high and low in initial autonomous motivation is important for their psychological well-being.

To summarize, for students low in initial relative autonomy, perceived instructor autonomy support related to better course performance; and for all students, perceived instructor autonomy support related to positive adjustment and to the students' becoming more autonomous over the semester, which in turn related to better performance.

Methodological limitations merit consideration in interpreting the findings. First, despite its prospective design, this study cannot establish clear causal relations between autonomy support and the dependent variables because autonomy support was not manipulated. Second, it would have been preferable to use a single assessment of leader autonomy support done in the middle of the term rather than taking the average of T1 and T2. Third, there was a larger than optimal attrition because the second questionnaire administration was conducted, unannounced, during the first full-class meeting after the last regular exam and about 100 participants missed that class. Although these students did not differ from those in the study sample on any T1 variables, the attrition is a limitation.

In conclusion, traditional models of introductory science instruction emphasize large-group lectures, limited interpersonal interactions between faculty and students, and a "sink-or-swim" atmosphere. Anecdotally, professors in such courses are often perceived as being low in autonomy support. The present study suggests that an instructional style low in autonomy support is likely to be related to students' feeling bad, and possibly to performing badly. In light of these results, it appears that shifts in teaching approaches toward providing more support for students' autonomy and active learning may hold promise for enhancing students' achievement and psychological development. To some extent this can be accomplished by having professors become more student-oriented, more accessible to students, and responsive to their needs and concerns. That, of course, would require willingness on the part of faculty to change their orientations, and promoting such willingness may be very difficult. Thus, one of the interesting aspects of The Workshop Chemistry Project (Gosser et al., 1996) is that it focuses on providing students with autonomy supportive instruction without requiring the faculty to change.

Specifically, the workshops supplement the lectures with a student-centered arena for discussing organic chemistry material as well as difficulties related to learning the material. Of course, the present study did not evaluate The Workshop Chemistry Project, so it remains to be seen whether that is a more effective approach than the traditional approach for teaching natural science. But, the Project's aim of supporting students' autonomy does seem to be an important facilitator of learning and adjustment, and more autonomy-supportive instruction would likely be helpful in other college-level natural science courses as well, whether that autonomy support is actualized through faculty members' becoming more autonomy supportive, through the addition of a workshop format, or through a combination of the two.

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