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A Motivational Model of Persistence in Science Education: A Self-Determination Theory Approach

Geneviève L. Lavigne and Robert J. Vallerand

Laboratoire de Recherche sur le Comportement Social

Département de Psychologie

Université du Québec à Montréal

Paule Miquelon

Department of Psychology

McGill University

Abstract

The purpose of this study was to propose and test a motivational model of persistence in science education. The model posits that science teachers' support of students' autonomy positively influences students' self-perceptions of autonomy and competence. These self-perceptions, in turn, have a positive impact on students' self-determined motivation toward science which leads to their intentions to pursue science education and eventually work in a scientific domain. This model was tested with high school students (n = 728). Results from univariate analyses of variance and from structural equation modeling analyses (with LISREL) were found to support the proposed model. In addition, a direct link was obtained between perceptions of competence and intentions to pursue a science education, indicating that higher levels of perceived competence predicted higher levels of persistence intentions. The present findings support Self-Determination Theory and open the way to future research from a motivational approach in this area.

Keywords: self-determination, science education, persistence

A Motivational Model of Persistence in Science Education: A Self-Determination Theory Approach

Science and technology play a crucial role in today's industrialized society. Accordingly, every country should thrive to keep students involved and interested in scientific matters. However, there appears to be a growing decline of interest for the sciences in the general population (Osborne, Simon, & Collins, 2003) which is a cause for great concern. This situation is generalized around the globe where graduates from mathematics/statistics, computer science, and engineering represented only 18.1% of students in France, 18.2% in the United Kingdom, 20.3% in Italy, 14.5% in New-Zealand, and 11.8% in the United States (The National Center for Education Statistics, 2003). The situation is even worse in Canada where only 7.3% of university level diplomas were awarded to physical sciences and technology graduates in 2003 (Statistics Canada, 2003).

A scientific career attainment is influenced by the early choices made by students. Students' need to enroll in many science courses as early as in high school in order to be able to direct their professional path within the sciences later on. Several factors are thought to influence young students' decision to pursue or not a career or at least an education in science (see Osborne et al., 2003). Among such factors, research has identified the role of teacher's behavior and students' motivation toward science (Cheong, Pajares, & Oberman, 2004; Ratelle, Larose, Guay, & Senécal, 2005; Zusho, Pintrich, & Coppola, 2003) as key elements in students' persistence within a science education. The purpose of the present study was to propose and test a motivational model incorporating the role of these two factors in students' decision to pursue a science-based education and eventually a career in the scientific area. This model is based on the well developed theories of intrinsic and extrinsic motivation (e.g., Csikszentmihalyi & Nakamura, 1989; Deci & Ryan, 2000; Vallerand, 1997). It is believed that this motivational model could shed some understanding on the social factors that influence students' motivation and, in turn, on the impact of students' motivation on their intentions to pursue studies and careers in science.

A Motivational Model of Persistence in Science Education

The proposed model, presented in Figure 1, is made up of four parts. First, the role of the social environment is addressed. Specifically, in line with Self-Determination Theory (SDT; Deci & Ryan, 1985, 1991, 2000), the level of autonomy supportive behaviors from science teachers is hypothesized to influence students' satisfaction of their basic human needs (i.e., self-perceptions of autonomy and competence) within science classes. In turn, these self-perceptions are hypothesized to have a direct influence on students' science motivation. Finally, the more self-determined their motivation toward science, the more likely it is that students will have the intention to pursue studies and eventually to work in a scientific field.

This model is theoretically supported by motivational theories such as Self-Determination Theory (SDT), Cognitive Evaluation Theory (CET; Deci & Ryan, 1985, 1991, 2000), and the Hierarchical Model of Intrinsic and Extrinsic Motivation (HMIEM; Vallerand 1997), and it is empirically supported by research in education (e.g., Vallerand & Bissonnette, 1992; Vallerand, Fortier, & Guay, 1997) which demonstrated that a similar model predicts which high school students are likely to persist and which are likely to dropout of school.

Motivation toward Science

A motivational approach that has been found to be useful in understanding students' motivation in an educational context is the distinction between intrinsic and extrinsic motivation (Csikszentmihalyi & Nakamura, 1989; Deci & Ryan, 1985, 1991, 2000; Ryan & Deci, 2000). Someone is intrinsically motivated when he or she does something for its own sake, for the pleasure experienced in the process (Deci, 1975). For instance, students who go to a science class for the fun of learning something new are intrinsically motivated. However, someone is extrinsically motivated when he or she engages in activities not for themselves but for instrumental reasons.

According to Deci and Ryan's (1985, 1991, 2000) SDT, motivation can be distributed along a continuum from high to low levels of self-determination. The most self-determined style of motivation is intrinsic motivation defined above. In addition, several types of extrinsic motivation have been proposed (Deci & Ryan, 1985) each with a different degree of self-determination. From a high to a low degree of self-determination, there is *identified regulation* where the individual's behavior reflects conscious values and is internalized as personally important (e.g., students who go to a science class to eventually reach the career they desire); *introjected regulation* which represents a partial internalization without completely accepting it as one's own (e.g., students who go to a science class to avoid feeling guilty); and *external regulation* which takes place when a behavior is performed for external rewards or constraints (e.g., students who take science courses because their parents told them to). Finally, *amotivation* is a motivational construct that is characterized by a relative lack of motivation (e.g., students who go to school without seeing any utility in it; Deci, Vallerand, Pelletier, & Ryan, 1991).

Much research has provided support for the validity of the different motivational constructs in a variety of contexts (see Vallerand, 1997; Vallerand & Ratelle, 2002) including education (e.g., Miquelon, Vallerand, Grouzet, & Cardinal, 2005; Vallerand et al., 1989, 1992, 1993) as well as the science education domain (e.g., Black & Deci, 2000; Williams & Deci, 1996).

Social Determinants of Science Motivation

Cognitive Evaluation Theory (CET; Deci & Ryan, 1985, 1991, 2000), which is a sub-theory of SDT, specifies the social determinants and processes that are likely to influence motivation. The theory suggests that social agents play a key role in influencing people's motivation through their support for their need of autonomy. Supporting students' autonomy implies allowing them the possibility to make some decisions so they can feel they have an active role in their education (Ames, 1992). Then, the satisfaction of people's needs of autonomy and competence influences their self-determined motivation (Deci & Ryan, 2000; Vallerand, 1997). Hence, social agents have a significant impact on students' motivation within a particular context (Ames, 1992) through the autonomy support they provide students. The proposed model posits that science teachers, especially, play an influential role in the development of students' motivation toward science. Research has shown that an autonomy-supportive teaching style represents an important variable that contributes to a high-quality relationship between teachers and students (Reeve, 2006).

Considerable research has supported the postulated impact of social agents on peoples' motivation. For instance, research in the health care domain (Williams, Gagné, Ryan, & Deci, 2002; Williams, Grow, Freedman, Ryan, & Deci, 1996; Williams et al., 2006) demonstrated that autonomy support from health professionals led to increases in patients' self-determined motivation toward weight lose maintenance and smoking cessation. Additional research in education also demonstrated that autonomy support from social agents such as teachers (Deci, Nezlek, & Sheinman, 1981; Guay & Vallerand, 1997; Hardre & Reeve, 2003; Ryan & Grolnick, 1986; Vallerand et al., 1997), parents (Grolnick & Ryan, 1989; Vallerand et al., 1997), and peers (Guay, Boivin, & Hodges, 1999) positively influences students' needs satisfaction of autonomy and competence.

Much less research has been conducted within the science education context. However, a recent study (Ratelle, Larose, Guay, & Senécal, 2005) showed that parents' autonomy support positively impacted on their children's needs satisfaction which predicted their persistence within their science program. In addition, Williams and Deci (1996) studied medical students and found that those who had autonomy-supportive instructors were becoming more autonomous in their learning over a 6-

month period. Finally, Black and Deci (2000) showed that teachers' autonomy support was related to students' perceptions of competence, interest, enjoyment, and performance in an organic chemistry course.

It is important to highlight that science teachers' autonomy support is not hypothesized to directly influence students' science motivation but rather to influence students' self-perceptions of competence and autonomy which, in turn, are expected to directly influence students' science motivation. Thus, students' needs satisfaction acts as a mediator between teachers' autonomy supportive style and students' motivation toward science (to this effect, see Guay & Vallerand, 1997; Reeve & Deci, 1996; Sarrazin, Vallerand, Guillet, Pelletier, & Cury, 2002; Vallerand & Reid, 1984; Vallerand et al., 1997).

Motivational Consequences

Recent research based on SDT has shown that self-determined motivation is related to important behavioral (e.g., persistence, future intentions) outcomes (see Ryan & Deci, 2000; Vallerand, 1997; Vallerand & Ratelle, 2002). The more self-determined the motivation, the more the person experiences positive outcomes, including persisting in the activity. This is because self-determination has been hypothesized to be associated with enhanced psychological adjustment (Deci, 1980; Deci & Ryan, 1985). Studies in the health care domain demonstrated that higher levels of self-determined motivation (i.e., greater internalization and integration of behaviors and values) is associated with better maintenance of weight loss among obese patients (Williams et al., 1996), greater long-term smoking cessation (Williams et al., 2006; Williams, Gagné, Ryan, & Deci, 2002), and greater adherence to medication programs (Williams, Robin, Ryan, Grolnick, & Deci, 1998).

In the education literature, numerous studies also demonstrated the advantages of a self-determined school motivation on students' academic outcomes (Deci et al., 1991). For instance, self-determined school motivation has been associated with greater persistence with learning a second language (Noels, Clément, & Pelletier, 2001). In addition, research on high school dropouts (Hardre & Reeve, 2003; Vallerand & Bissonette, 1992; Vallerand et al., 1997) has shown that students' self-determined motivation toward school influences their intentions to pursue with their education while a non-self-determined motivation toward school influences students' intentions to drop-out.

The situation is similar within the science education literature where self-determined motivation has been found to be associated with positive consequences. A study by Hanrahan (1998) demonstrated that higher levels of intrinsic motivation were associated with greater cognitive engagement in a year-11 biology class compared with non-self-determined extrinsic motivation. Similarly, in a study with fourth-year medical students (Williams, Weiner, Markakis, Reeve, & Deci, 1994), it was found that instructors' autonomy-support and students' self-determined motivation influenced students' choice to become committed to a program of internal medicine residency. Finally, Black and Deci (2000) also found that students' self-determined motivation was positively related to their persistence in a difficult organic chemistry course.

The model proposed in the present study uses students' intentions to pursue their education and eventually work in a scientific domain as a behavioral measure of outcome. Measuring students' intentions is of evident importance in the domain of education because students' are expected to form intentions and make actual choices in line with such intentions early in their education. Much research reveals that intentions are significant predictors of behavior (Ajzen & Fishbein, 1980; Brickell, Chatzisarantis, & Pretty, 2006; Carpenter & Fleishman, 1987). For instance, Schoon (2001) did a 17-year follow-up study of a representative cohort of over 7000 individuals in the United Kingdom and he demonstrated that career intentions at age 16 significantly predicted the actual career attainment at age 33. Hence, students who form intentions to pursue high-school science courses or to direct their education toward a scientific major are more likely to end up having a scientific career.

Another important issue within the field of science education pertains to gender differences. Research reveals that girls are still less likely to choose a career in science than boys and are still holding negative attitudes toward science (Jones, Howe, & Rua, 2000; Weinburgh, 1995). According to the US National Science Foundation (2000), women represent 63% of psychologists, 55% of sociologists, but only 10 % of physicists and 9% of engineers. This lack of involvement in science might be influenced by numerous factors including gender stereotypes. For example, in a study with 4^{th}, 5^{th}, and 6^{th} grade students, Farenga and Joyce (1999) found that physical and technology-related courses were perceived by both gender as more appropriate for boys. Other research has also shown that boys perceive themselves as being more competent than girls in science-related courses. Furthermore, it appears that this distinction between boys and girls' perceptions of competence is magnified when gender stereotypes are made salient (Désert, Croizet, & Leyens, 2002; Guimond & Roussel, 2001, 2002; Guimond, Chatard, Martinot, Crisp, & Redersdorff, 2006).

The purpose of the present study was to propose and test the motivational model depicted in Figure 1. This model posits that science teachers' support of their students' autonomy positively influences students' self-perceptions of autonomy and competence. These, in turn, are hypothesized to facilitate students' self-determined motivation toward science which is hypothesized to positively influence their intentions to pursue an education and eventually a career within the sciences. This model is hypothesized to be gender invariant, implying that the posited motivational sequence will be the same for girls and boys. However, gender differences are hypothesized at the mean level such that girls' measures of self-perceptions of competence and girls' intentions to persist in science education should be lower than boys'.

Method

Participants

Participants were 728 10th-grade French-Canadian students (349 boys and 367 girls; 12 did not indicate their gender). Participants' mean age was 15.14 years (SD=.45); where 81% of them were 15 years of age. Participants were recruited from three Montreal public high schools.

Questionnaire

Motivation toward science. Participants completed a 16-item scale measuring their motivation toward science courses. This scale was based on Ryan and Connell (1989) and contained four subscales focusing on different facets of students' science class activities (i.e., "in general, why do you go to your science classes", "in general, why do you do your in-class science exercises", "in general, why do you do your science homework", and "in general, why do you listen to your science teachers"). Each subscale contained four items associated with a different degree of self-determined motivation: intrinsic motivation (e.g., "for the fun of doing it"; α=.89), identified regulation (e.g., "because I choose to do it for my own good"; α=.85), introjected regulation (e.g., "because it is what I am supposed to do"; α=.88), and amotivation (e.g., "I don't know, I don't see what it brings me"; α=.90).

Need satisfaction. This measure assessed students' science-related self-perceptions of competence (e.g., "I believe I have a natural talent for science"; 3 items, α=.90) and autonomy (e.g., "I feel obligated to go to my science classes" reversed score; 3 items, α=.74).

Autonomy support. This scale measured students' perceptions of their teachers' autonomy support (e.g., "my science teachers often ask for my opinion about science-related material"; 3 items, α=.60).

Future intentions. This scale measured students' intentions to pursue their education and eventually a career within the sciences (e.g., "I have the intention of taking some science classes next year" and "I would like to have a scientific career"; 6 items, α=.93). All of the above items were scored on a 7-point Likert scale, ranging from (1) *not at all in agreement* to (7) *very highly in agreement*.

Demographic Variables. Finally, demographic questions assessed students' age, gender, nationality, language spoken at home, birth place, and each parent's working status.

Procedure

Students were asked to complete the questionnaire described above in class. The questionnaire was administered by a trained experimenter according to standardized instructions. It was explained that the purpose of the questionnaire was to learn more about students' attitudes and behaviors toward science. Science classes were described as including every science courses they were enrolled in that particular academic year. It was clearly stated that the confidentiality of their answers would prevail at all time. Following these instructions, students' questions were answered and they completed the questionnaire individually. Afterwards, they were all thanked for their participation.

Results

Motivation toward School and Behavioral Intentions

Students were divided in two groups (i.e., high vs. low future science intentions) based on their average score from the six future intentions items. The cut-off point was set at 4 from the 7-point Likert scale ranging from (1) *not at all in agreement* to (7) *very highly in agreement* resulting in a high intentions group composed of 425 students and a low intentions group composed of 303 students. A 2 (type of science intentions: high vs. low) × 2 (gender) × 4 (type of science motivation: intrinsic vs. identified vs. introjected vs. amotivated) analysis of variance (ANOVA) with repeated measures on the motivation variable was performed on the data. This design allowed us to test for the presence of a Type of science intentions × Motivation interaction, in which students with high intentions toward science are expected to score higher on the self-determined forms of motivation (i.e., intrinsic motivation and identified regulation) but lower on non-self-determined types of motivation (i.e., introjected regulation and amotivation).

Results revealed a significant main effect for the science motivations subscales, F (2.23, 2028) = 711.89, $p < .0001$ and a significant main effect for the type of science intentions, F (1, 31) = 22.81, $p < .0001$. Of greater interest, as expected, a significant Type of science intentions × Motivation interaction was found, F (2.23, 218) = 76.35, $p < .0001$. Simple effect analyses indicated that all science motivation subscales yielded significant differences between the two types of science intentions. More precisely high science intentions students were found to be more intrinsically motivated ($p < .0001$) and identified regulated ($p < .0001$) than low science intentions students. Conversely, low science intentions students had higher levels of introjected regulation ($p < .0001$) and of amotivation ($p < .0001$) than high science intentions students. The means and standard deviations for the four motivation subscales as a function of intentions to persist in science education are displayed in Table 1. Additionally, results revealed a nearly significant Gender × Motivation interaction, F (2.23; 7.95) = 2.79, $p = 0.056$. However, simple effect analyses yielded no significant ($p<.05$) difference between boys and girls on the motivation subscales.

Science Teachers' Autonomy Support and Students' Perceptions of Autonomy and Competence as a Function of Future Intentions

A 2 (type of science intentions: high vs. low) × 2 (gender) ANOVA on students' perceptions of their science teachers' autonomy support was also conducted. A significant main effect for the type of science intentions was found, F (1, 21) = 13.16, $p < .0001$. As expected, results revealed that students with high science intentions perceived their science teachers as supporting significantly more their sense of autonomy than low science intentions students. No main effect for gender and no interaction between type of science intentions and gender were found on this variable.

We also conducted two 2 (type of science intentions: high vs. low) × 2 (gender) ANOVAs on students' self-perceptions of autonomy and competence variables. A significant main effect for the type of science intentions was found on the perceptions of autonomy scale, F (1, 292) = 156.19, $p < .0001$. No main effect for gender was found on this variable. A significant main effect for the type of science intentions was also found on the perceptions of competence scale, F (1, 475) = 293.22, $p < .0001$. These results revealed that students with high intentions to pursue their schooling in science perceived themselves as more autonomous and more competent in science than students with low intentions for a science education. A significant gender main effect for the perceptions of competence variable was also found, F (1, 26) = 16.04, $p < .0001$, indicating that boys (M=4.56) perceived themselves as more competent in science than girls (M=3.96). No interaction between science intentions and gender was found on this variable. Finally, results revealed a significant mean difference ($p < .0001$) between boys (M=4.48) and girls (M=3.97) on the future science intention variable. The means and standard deviations for all variables as a function of intentions to persist in science education appear in Table 2.

The Science Motivational Model: Path Analysis

In order to use a single motivation score in the path analysis, a self-determined motivation index was constructed by a summation of specifically weighted scores from the different motivational subscales according to their position on the self-determination continuum [i.e., 2 * (intrinsic motivation score) + 1 * (identified regulation score) - 1 * (introjected regulation score) – 2 * (amotivation score); see Vallerand, 1997]. Overall, seventeen cases were found to be multivariate outliers (p <.001) (Tabachnick & Fidell, 2001). All seventeen outliers were deleted, leaving 711 cases for the analyses. Table 3 presents the correlation matrix involving all variables for these participants. The hypothesized model was tested using a path analysis with LISREL 8. The covariance matrix served as database for the path analysis and the method of estimation was maximum likelihood. The model contained 1 exogenous variable (i.e., autonomy support) and four endogenous variables (i.e., perceptions of competence, perceptions of autonomy, science motivation, and intentions). Paths were specified according to the hypotheses of the theoretical model. In addition, a positive covariance was estimated between perceptions of autonomy and competence disturbance terms because these two variables were assumed to positively covary. Finally, because a prior test of the model revealed the presence of two supplemental paths from perceptions of competence and perceptions of autonomy to intentions, these were included in the final model. Results of the path analysis revealed a satisfactory fit of the model to the data. The chi-square value was not significant, χ^2 (df =2, N=711) = 5.78, $p > .05$ and the other fit indices were highly acceptable, NNFI = .99, CFI = .98, RMSEA = .05, GFI = 1.00, and NFI = 1.00, therefore indicating good model fit.

As shown in Figure 2, the estimated paths between autonomy support and perceptions of autonomy ($\gamma = .28$) and perceptions of competence ($\gamma = .17$) were both significant (t value > 3.29). Likewise, the estimated path between perceptions of autonomy and science motivation (ß = .57) as well as that between perceptions of competence and science motivation (ß = .17) were both significant. Moreover, the estimated path between science motivation and intentions was also significant ($\beta = .16$). Finally, the estimated path between perceptions of autonomy and intentions (ß = .16) as well as that between perceptions of competence and intentions (ß = .50) were both significant.

The same motivational model was also tested separately for boys and girls. Twelve participants did not indicate their gender; therefore they were excluded from the analysis. The boys only sample contained 342 participants and the correlational matrix involving all variables for these participants is presented in Table 4. Results of the path analysis revealed a satisfactory fit of the model to the data. The chi-square value was not significant, χ^2 (df = 2, N=342) = 3.98, $p > .05$ and the other fit indices were highly acceptable, NNFI= .98, CFI = 1.00, RMSEA = .05, GFI = 1.00, and NFI = .99, therefore indicating good model fit. As shown in Figure 3, the estimated paths between autonomy support and perceptions of autonomy (γ = .30) and perceptions of competence (γ = .20) were both significant (t value > 3.29). Likewise, the estimated path between perceptions of autonomy and science motivation (ß = .53) as well as the estimated path between perceptions of competence and science motivation (ß = .21) were both significant. Moreover, the estimated path between science motivation and intentions was also significant (β= .12). Finally, the estimated path between perceptions of autonomy and intentions (ß = .14) as well as that between perceptions of competence and intentions (ß = .56) were both significant.

The girls only sample contained 357 participants and the correlational matrix involving all variables for these participants is presented in Table 5. Results of the path analysis revealed a satisfactory fit of the model to the data. The chi-square value was not significant, χ^2 (df= 2, *N*=357) = 5.00, p > .05 and the other fit indices were highly acceptable, NNFI= .98, CFI = 1.00, RMSEA = .07, GFI = 1.00, and NFI = .99, therefore indicating good model fit. As shown in Figure 4, the estimated paths between teacher autonomy support and perceptions of autonomy (γ = .25) and perceptions of competence (γ = .15) were both significant (t value > 3.29). Likewise, the estimated path between perceptions of autonomy and science motivation (ß = .60) as well as the estimated path between perceptions of competence and science motivation (ß = .16) were both significant. Moreover, the estimated path between science motivation and intentions was also significant (β= .19). Finally, the estimated path between perceptions of autonomy and intentions (ß = .17) as well as that between perceptions of competence and intentions (ß = .43) were both significant.

To verify whether the hypothesized model was actually invariant across gender or not, a multi-sample path analysis was performed on the data. This kind of analysis involves the estimation of a structural model of observed variables across two or more groups (Kline, 2005). By constraining all model coefficients (i.e., all path coefficients, the covariances, and error terms) to be equal between the boys only sample and the girls only sample, we can determine if the hypothesized model equally fits the data for each gender. Results of the multi-sample path analysis revealed a satisfactory fit of the model to the data. The chi-square value was not significant, χ^2 (df = 16, N=342) = 24.93, $p > .05$ and the other fit indices were highly acceptable, NNFI= .99, CFI = .99, RMSEA = .04, GFI = .99, and NFI = .98, therefore indicating good model fit. It can therefore be concluded that the hypothesized model is invariant across gender.

Discussion

The purpose of this study was to test a motivational model of persistence in science education. The model suggests that science teachers' support of their students' autonomy would influence students' own sense of autonomy and competence toward science. In turn, these self-perceptions were hypothesized to influence students' science motivation, subsequently leading to intentions to pursue their education in science, and eventually to pursue a career in a scientific domain. The results from the structural equation modeling (SEM) analyses provided support for the proposed model. Significant direct links were also found between students' perceptions of competence and autonomy on the one hand and future intentions, on the other. As expected, the motivational sequence was found to be invariant for gender.

In addition, results comparing students with high and low intentions to continue their science education provided additional support for the model. Students with high intentions to pursue a science education reported significantly higher levels of intrinsic motivation and identified regulation and lower introjected regulation and amotivation than students with low science intentions. Mean differences were also found on the antecedent and mediating variables of students' science motivation.

Specifically, high science intentions students systematically reported higher levels of autonomy support from their science teachers along with greater self-perceptions of autonomy and competence. Finally, boys had higher levels of perceptions of competence and intentions to persist in science education than girls. Overall, the findings lead to a number of implications.

Implications for Intrinsic-Extrinsic Motivation Theory and Research

One implication of the present findings is that they provide further support for SDT (Deci & Ryan, 1985, 1991, 2000). As hypothesized by SDT, the more self-determined participants' science motivation, the more likely they should consider an education and a career within a scientific field. This is exactly the pattern of findings that were obtained. The present results are also in agreement with motivational research from the education literature. A prospective study by Vallerand and Bissonnette (1992) demonstrated that college students who had higher levels of self-determined motivation at the beginning of the semester were more likely to complete the semester than those who had lower levels of self-determined motivation. A subsequent study on high school students (Vallerand et al., 1997) also demonstrated that students with high levels of self-determined motivation had higher intentions to remain in school which led them to actually persist over the entire academic year. Thus, students' intentions to persist in science education should, over time, play a causal role in future science decisions and behaviors (to this effect, see Chatzisarantis, Hagger, Smith, & Phoenix, 2004; Vallerand et al., 1997).

On the Role of the Social Environment in Motivation toward Science

An additional implication is that the results from the path analysis revealed that science teachers can be seen as influencing students' science motivation through their impact on students' self-perceptions of autonomy and competence. These findings are in line with past research (Guay & Vallerand, 1997; Miserandino, 1996; Noels, Clément, & Pelletier, 2001). For instance, in a study with students in lower-level Spanish classes (Noels, 2001), results from path analyses revealed that teachers' autonomy-supportive behaviors influenced students' perceived autonomy and perceived competence which, in turn, were related to students' motivation toward the Spanish course. The more students perceived themselves as autonomous and competent, the more self-determined was their motivation.

The issue of the role of autonomy support in facilitating perceptions of autonomy is rather straightforward. However, that of autonomy support in perceptions of competence is less so. The present results suggest that teachers who promote the autonomy of their students will also increase their perceptions of competence in science subjects. It thus appears that providing students with choice and opportunities for autonomy is likely to positively affect how competent they perceive themselves. Indeed, if a teacher leaves room for students to make choices and decisions, the implied message is that the students are competent enough to act on their own. Similar findings have been obtained with elementary students (Deci et al., 1981).

Also noteworthy is the relative impact of perceptions of autonomy and competence on self-determined motivation. The present findings revealed that perceptions of autonomy had a much more important link to self-determined motivation than perceptions of competence (Betas of .57 and .17, respectively in the overall model). These findings are in line with past research (Grouzet et al., 2005; Guay & Vallerand, 1997; Sarrazin et al., 2002; Vallerand et al., 1997). Future research is needed to determine if the same results hold for all cultures or only for cultures where autonomy is promoted as an important value such as in North-America (Triandis, 1995).

The direct link from perceived competence to future science intentions is also consistent with considerable work on the psychological construct of self-efficacy (Betz & Hackett, 1983; Hackett & Betz, 1989). Such research has underscored the significance of perceived mathematic self-efficacy on actual selection of mathematic and science courses or college majors. The importance of mathematic self-efficacy was consistently observed to be a more important predictor of mathematic or science career choices than actual mathematic performance and achievement variables. In his self-efficacy theory, Bandura's (1986) posits that self-efficacy beliefs mediate the effect of skills on subsequent performance through its influence on effort, persistence, and perseverance. Recent research in science education (Guimond & Roussel, 2002; Zusho et al., 2003) has also underscored the role of perceived competence in outcomes such as science career intentions, learning, and course performance.

However, these findings slightly depart from earlier research where the impact of perceptions of competence on behaviors and outcomes were fully mediated by self-determined motivation (Grouzet et al., 2005; Guay & Vallerand, 1997; Sarrazin et al., 2002; Vallerand et al., 1997). It is possible that the science field represents a special case wherein behaviors and decisions are not only based on one's interest and motivation toward scientific issues but also on a perception that one has the abilities and skills to do well in such subjects. For instance, if one loves engaging in practical science projects but is doing poorly in math, it is unlikely that this person will choose a scientific career because of potential schooling problems that can be foreseen. Future research is needed in order to more fully understand this partial mediational role of motivation and determine if it applies to other educational fields where abilities and talent are crucial (e.g., a musical education and career). Such research may lead to some refinements in SDT.

On the Gender Issue

Another purpose of the present study was to explore the issue of gender differences in the scientific field. Women represent close to half of the work force but only a quarter of the high-status scientific positions (National Science Board, 2000). A similar trend was apparent in the present sample as fewer girls (n=191) intended to pursue an education and a career in science than boys (n=224). This effect was likely due to the fact that girls reported lower levels of perceived competence than boys. To the extent that girls feel less competent, it appears that they are less likely to pursue a scientific career. Future research is needed to identify the roots of such gender differences in perceptions of competence.

A puzzling result emerged from our study: girls did not exhibit a less self-determined motivation toward science than boys even though they had lower positive self-perceptions of competence. Much research reveals that women's motivation is systematically more self-determined than men's motivation across several life domains (e.g., Ratelle et al., 2005; Vallerand & Bissonnette, 1992; Vallerand et al., 1997). In order to better understand the lack of gender effect on science motivation in the present study, we compared the means for each type of science motivation (i.e., intrinsic, identified, introjected, and amotivated) between the present sample and the ones reported by Vallerand et al. (1997) in their study with over 4500 high school students. They had used a scale similar to ours and their participants were of similar ages. Results revealed that girls' intrinsic motivation and identified regulation were significantly lower ($p<.01$) in the present study while no differences were found for introjected regulation, amotivation, as well as for boys between the two studies. Furthermore, while in the Vallerand et al. (1997) study girls reported a more self-determined motivation than boys, no differences were found in the present study. Hence, it would appear that girls' science motivation might actually be lower than their motivation for other educational domains, possibly because of their lower perceptions of competence in science. Future research could benefit from a deeper exploration of these gender differences and how they relate to behavior and decisions to pursue a science education and career.

On the Issue of Persistence in Science Education

The present results shed new light on the issue of students' persistence in science education. Specifically, they underscored the fact that a crucial social factor, namely teachers seem to trigger a causal sequence where facilitating students' needs satisfaction predicted higher levels of self-determined science motivation, which, in turn, predicted greater intentions to pursue an education and eventually a professional career in a scientific domain. It would thus appear that teachers' autonomy support of their students plays a key role in students' intentions to continue in a science education. In that light, it is noteworthy that Reeve and colleagues' (1998, 2004) research showed that teachers can be trained to support their students' autonomy and that these training sessions can positively affect students' motivation. For instance, Reeve et al. (2004) showed that a 1-hour after school informational session (and additional information via a study specific website) on how to be autonomy supportive with students was sufficient to increase teachers' autonomy support in class compared to a control group of teachers as assessed by a trained observer. Furthermore, teachers in the autonomy-support group had students with higher levels of classroom involvement only two weeks after the informational session than students with teachers in the control group. Future research based on Reeve's approach could lead to fruitful interventions in the hope of increasing students' motivation to pursue a scientific education and career. However, in light of the findings of the present study that underscore the role of perceptions of competence in deciding to pursue a scientific education and career, it would also appear important that interventions focus on improving students' sense of competence toward science (to this effect see Bandura and Schunk, 1981).

Limitations

Several limitations can be noted. First, only one type of social agents was assessed in the present study, namely teachers. Future research should assess the role of other significant individuals such as parents and school administrators (Vallerand et al., 1997), as well as peers (Guay et al., 1999), in science motivation. A second limitation deals with the fact that teachers' autonomy support was based on students' own perceptions rather than through the assessment of trained observers. However, research (see Smith, Smoll, & Curtis, 1979) reveals that children's perceptions of adults' behaviors correlate more strongly with that of trained observers than adults' self-report of their own behaviors. It would thus appear that students' perceptions of their teachers may have high levels of validity. Nevertheless, future research would do well to replicate the present findings with a more objective assessment of teachers' autonomy support. A third limitation of the present study relates to the self-report nature of the data. Future research using data from other sources (e.g., parents-report, peer-report) would be highly informative. Furthermore, it would be interesting to determine if students' actual science achievement has an impact on the autonomy support they receive from teachers. It might be that the higher students' performance in science subjects, the more autonomy support they receive from their teachers which subsequently influences their self-perceptions of autonomy and competence. A fourth limitation of the present study concerns the design which was correlational in nature. Although structural equation modeling techniques provide a glimpse on the potential causal links among the model variables, no causal conclusions can be drawn from such analyses. However, past experimental research (e.g., Koestner et al., 1984; Reeve et al., 2004) has shown that autonomy support and controlling behaviors from teachers do indeed produce positive and negative effects, respectively, on intrinsic motivation. Nevertheless, future research using experimental designs should be used to replicate and confirm the present findings.

In sum a motivational model of persistence in science education was proposed and generally supported. We believe that the present findings contribute to our understanding of the psychological processes through which social factors influence science motivation and future intentions to persist in that area. Future research is needed, however, in order to shed light on the intricacies through which social factors and motivation operate in the prediction of behavior in science education.

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Author Notes

Geneviève L. Lavigne and Robert J. Vallerand, Laboratoire de Recherche sur le Comportement Social, Département de Psychologie, Université du Québec à Montréal; Paule Miquelon, Department of Psychology, McGill University. The research was facilitated by grants from the Social Science and Humanities Research Council (SSHRC) and by the Fonds de Recherche sur la Société et la Culture (FQRSC) to the second author. Correspondence concerning this paper should be addressed to Robert J. Vallerand, Laboratoire de Recherche sur le Comportement Social, Université du Québec à Montréal, Box 8888, Succursale Centre-Ville, Montréal (Québec) Canada, H3C 3P8. Electronic mail can be sent to vallerand.robert_j@uqam.ca.

Table 1

Means and Standard Deviations of the Motivational Subscales as a Function of Intentions to Persist in Science Education

	High Intentions Students (n = 425)		Low Intentions Students (n =303)		
Subscale	M	SD	M	SD	*p*
Intrinsic Motivation	3.52	1.47	2.39	1.27	.0001
Identified regulation	5.51	1.27	4.58	1.51	.0001
Introjected regulation	4.39	1.74	5.15	1.58	.0001
Amotivation	1.68	0.91	2.16	1.23	.0001

Note. Scores ranged from 1 to 7 and are based on 4 items for each of the four motivational subscales.

Means differ significantly at *p* value listed.

Table 2

Means and Standard Deviations for Motivational Antecedent and Mediating Variable's Subscales as a Function of Intentions to Persist in Science Education

	High Intentions Students (n = 425)		Low Intentions Students (n =303)		
Subscale	M	SD	M	SD	*p*
Perceived autonomy	5.58	1.21	4.28	1.56	.0001
Perceived competence	4.98	1.24	3.26	1.34	.0001
Perceived science teachers' autonomy support	3.18	1.31	2.82	1.22	.0001

Note. Scores ranged from 1 to 7 and are based on 3 items for perceived autonomy, perceived competence, and perceived science teachers' autonomy support

Means differ significantly at *p* value listed.

Table 3

Correlation Matrix Involving all Variables of the Persistence in Science Education Motivational Model

	M	SD	Science Motivation	Perceptions of competence	Perceptions of autonomy	Autonomy Support
Intentions	4.25	1.92				
Science Motivation	11.43	23.72	.48**			
Perceptions of competence	4.27	1.51	.64**	.44**		
Perceptions of autonomy	5.07	1.49	.50**	.65**	.48**	
Teacher Autonomy Support	3.05	1.28	.15**	.25**	.17**	.28**

*Note. N= 711, ** p < .01*

Table 4

Correlation Matrix Involving all Variables of the Persistence in Science Education Motivational Model for Boys

	M	SD	Science Motivation	Perceptions of competence	Perceptions of autonomy	Autonomy Support
Intentions	4.47	1.81				
Science Motivation	10.81	23.70	.46**			
Perceptions of competence	4.55	1.45	.68**	.45**		
Perceptions of autonomy	5.11	1.44	.47**	.63**	.45**	
Teacher Autonomy Support	3.12	1.31	.20**	.28**	.20**	.30**

*Note. N= 342, ** p < .01*

Table 5

Correlation Matrix Involving all Variables of the Persistence in Science Education Motivational Model for Girls

	M	SD	Science Motivation	Perceptions of competence	Perceptions of autonomy	Autonomy Support
Intentions	4.01	2.00				
Science Motivation	11.70	23.82	.51**			
Perceptions of competence	3.98	1.53	.60**	.45**		
Perceptions of autonomy	5.03	1.54	.52**	.68**	.50**	
Teacher Autonomy Support	2.98	1.25	.09	.23**	.15**	.25**

*Note. N= 357, ** p < .01*

Figure Captions

Figure 1. Hypothesized Motivational Model of Science Education

Figure 2. Results of the Path Analysis for the Science Education Motivational Model

Figure 3. Results of the Path Analysis for the Science Education Motivational Model for Boys

Figure 4. Results of the Path Analysis for the Science Education Motivational Model of for Girls

***Figure 1*. Hypothesized Motivational Model of Science Education**

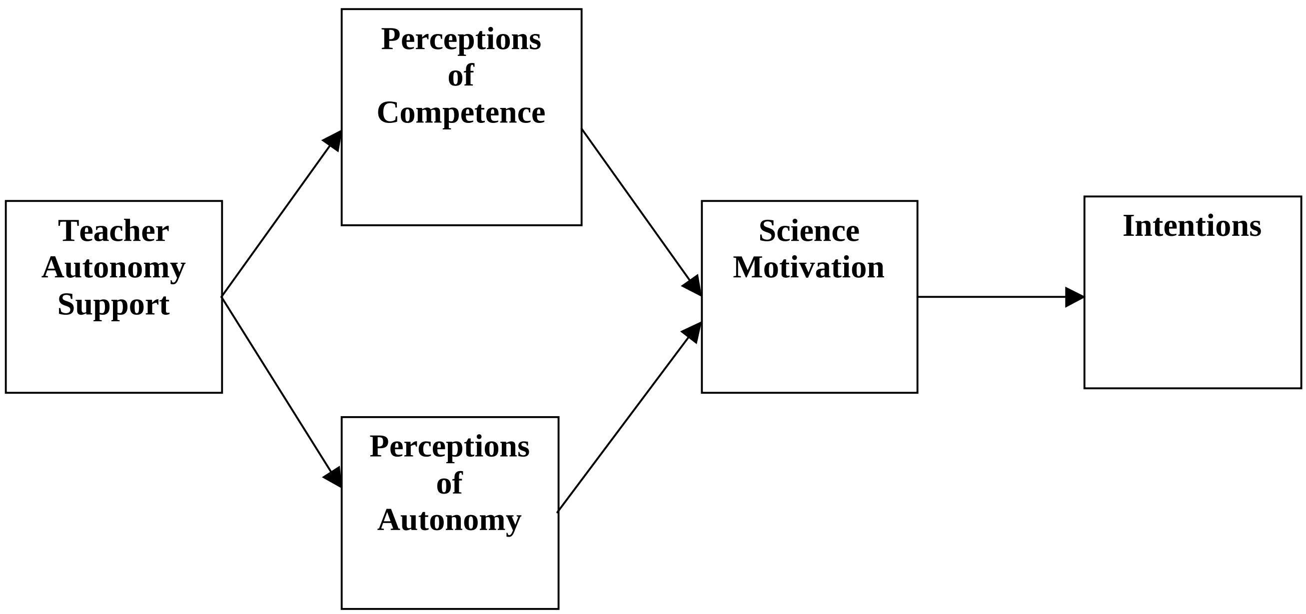
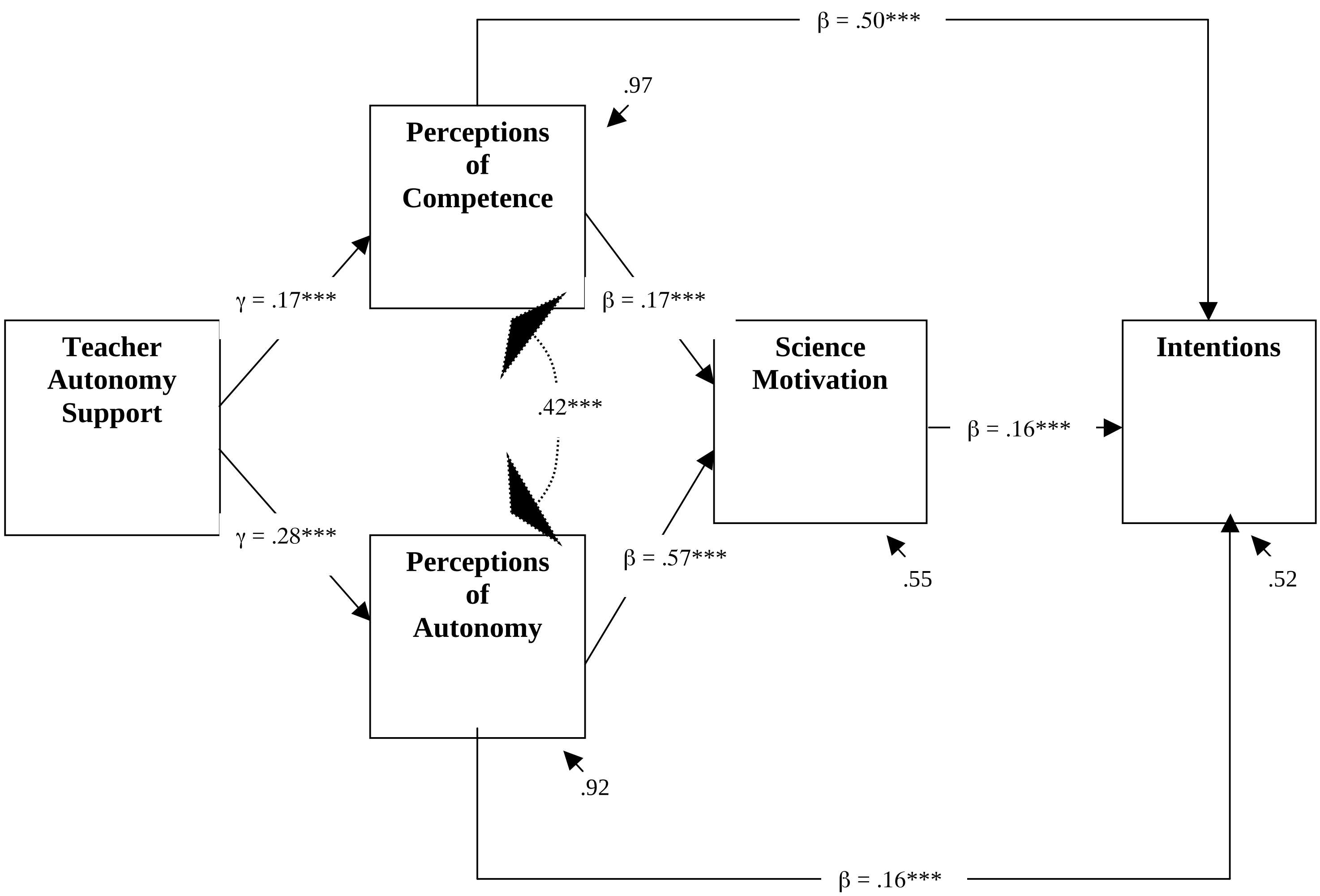
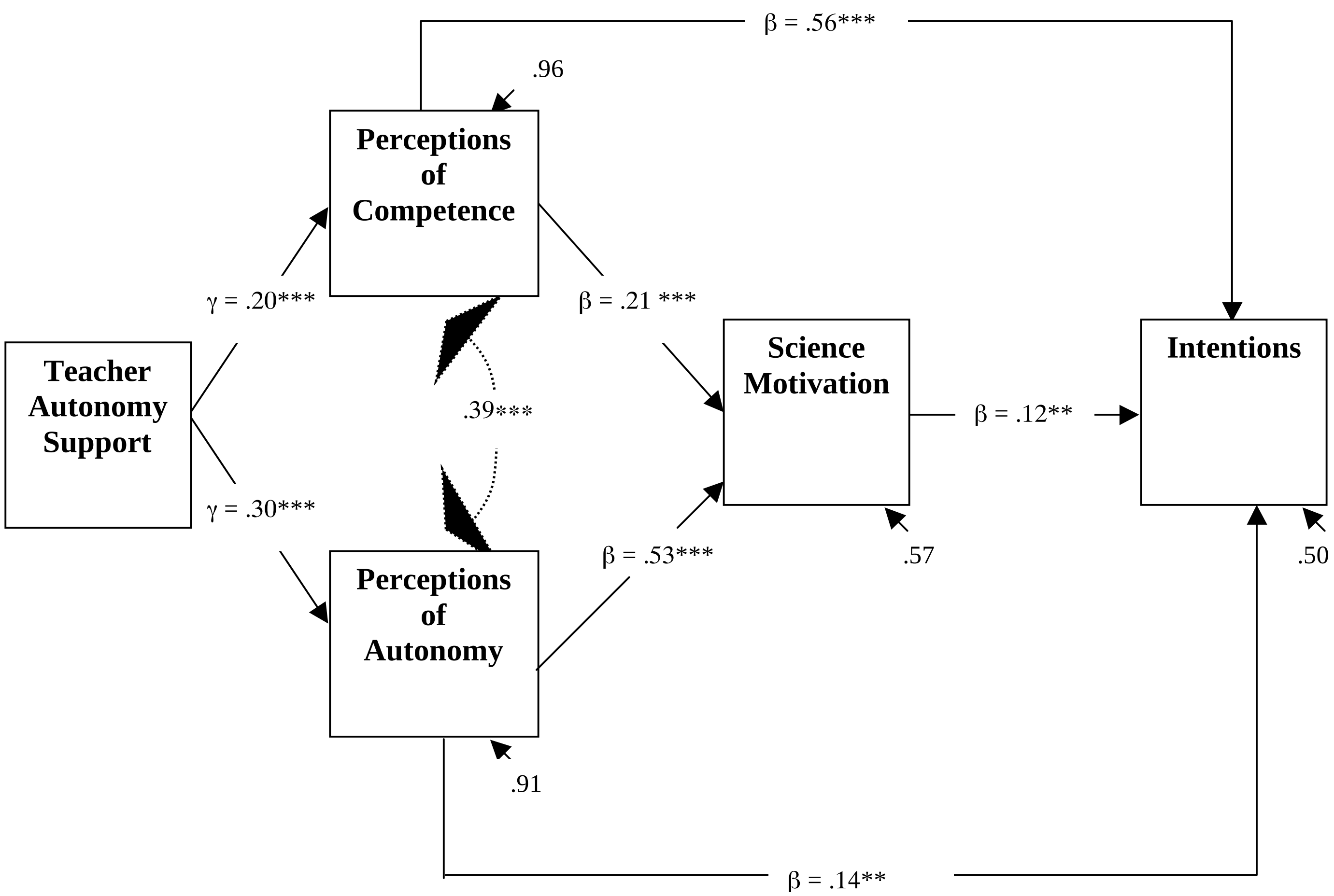


***Figure 2*. Results of the Path Analysis for the Science Education Motivational Model**



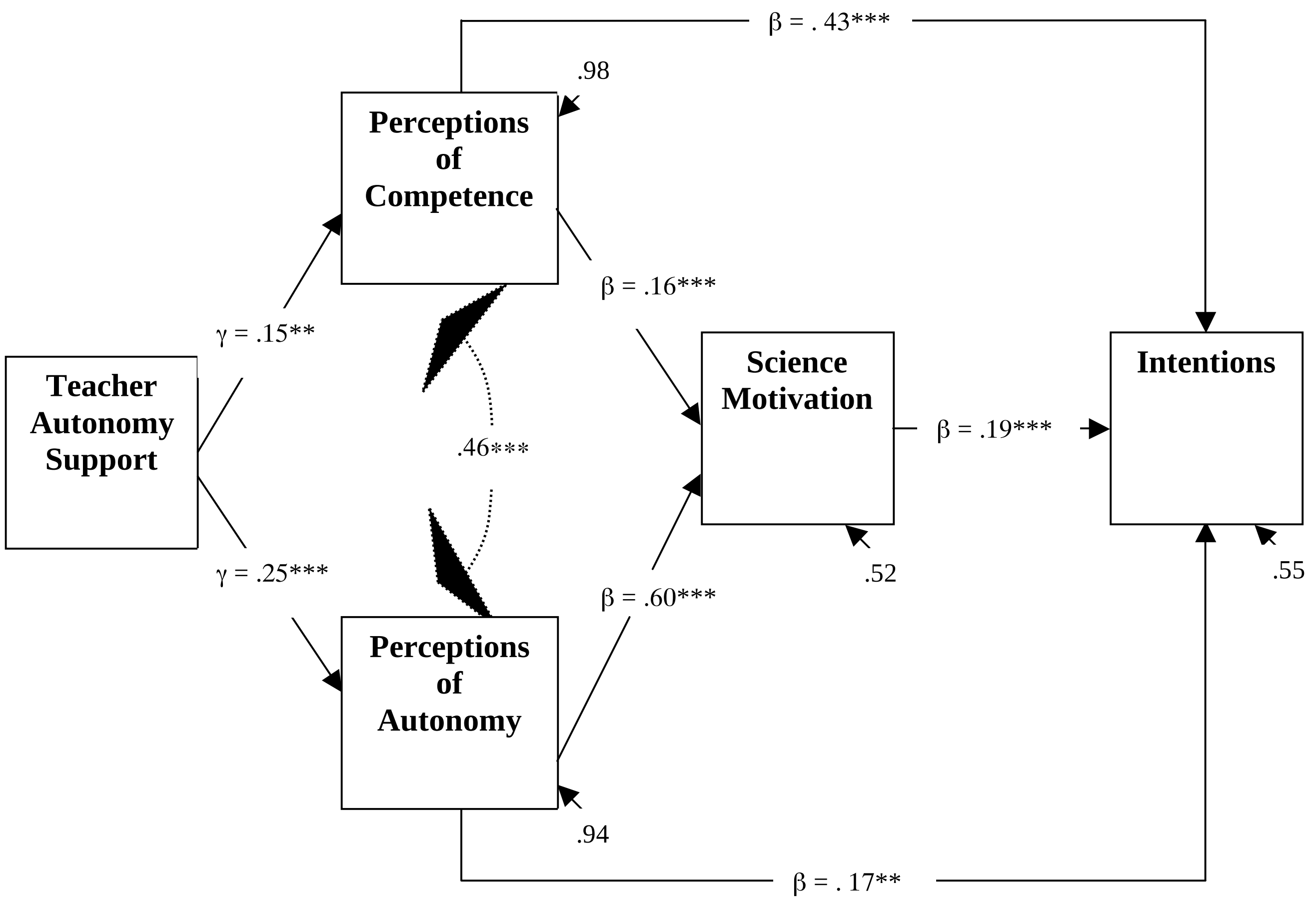
*Note. *** p < .001*

Figure 3. **Results of the Path Analysis for the Motivational Model of Science Education for Boys**



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

Figure 4. **Results of the Path Analysis for the Science Education Motivational Model for Girls**



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