Student, Teacher, and School Context Variables Predicting Academic Achievement in Biology: Analysis from a Multilevel Perspective

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Abstract

The current investigation analyzed how student variables and context variables predicted high school students' academic achievement. The participants were 988 twelfth graders and their corresponding 57 Biology teachers. Data were analyzed using the multilevel method. Results indicate that 85.6% of the variation observed in Biology achievement was explained by variables at the individual level, while the remaining 14.4% was explained by variables at the class level. At the individual level, Biology achievement was associated with approaches to learning, prior knowledge, class absence, and parents' education level. At the class level, academic achievement was only associated with teachers' approaches to teaching, not directly, but through students' approaches to learning.

Keywords: Approaches to teaching, approaches to learning, Biology achievement, multilevel analysis.

Resumen

En el presente estudio se analiza la contribución de variables del alumno y variables del contexto en la predicción del rendimiento académico en Bachillerato. Se han obtenido información de 988 estudiantes, de último curso de Bachillerato y de sus 57 profesores de Biología. Los datos fueron analizados desde una perspectiva multinivel. Los resultados indican que, de la variabilidad observada en el rendimiento en Biología, el 85.6% se debe a las variables de nivel de estudiante mientras que el 14.4% restante corresponde a las variables de nivel de clase. A nivel de estudiante, el rendimiento en Biología se encontró asociado con el enfoque de aprendizaje, con los conocimientos previos, con el absentismo escolar y con el nivel educativo de los padres. A nivel de clase, el rendimiento únicamente estuvo asociado con el enfoque de enseñanza del profesor, y no directamente, sino a través del enfoque de estudio del alumno.

Palabras clave: Enfoques de enseñanza; enfoques de aprendizaje; rendimiento en Biología; análisis multinivel.

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Introduction

Consistent with the 2003 and 2006 PISA (OCDE, 2010) reports, in 2009, the students of Portugal and Spain once again obtained results in the Sciences (493 and 488, respectively) that were lower than the OCDE mean (501), suggesting the need to understand these results. After analyzing the impact of social macro-structures and focusing on the teaching-learning process, this report states that economic variables in each country (specifically, the gross domestic product) only explain 6% of the differences in achievement found in the diverse educational systems. This result represents a challenge to investigate the variables that explain the remaining 94% of variance in academic achievement of high school students. The present investigation seeks to deepen our understanding of the conditions that determine academic achievement in high school. We will attempt to respond to this challenge by analyzing the contribution of various theoretically relevant student variables (e.g., approaches to learning, prior achievement, study time, class absence, homework), as well as contextual variables (e.g., approaches to teaching, teacher gender, teacher experience, class size, parents' educational level). As the data are organized in a hierarchical structure (students are nested in classes with their respective teacher), we used a multilevel analysis strategy in this study, which allowed examination of intraclass and interclass effects.

Student variables and academic achievement

Approaches to learning

Three decades ago, Marton and Säljö (1976) described two different approaches employed by students to deal with academic texts. This study initiated an important line of research focused on what was referred to as students' *approaches to learning* (Entwistle, 2009). The authors identified a deep level and a surface level of processing, depending on the approach to learning used by the student to deal with the task. Students who prefer a surface approach are motivated by a goal that is extrinsic to the learning-task; their task involvement is low, and they expend the minimal effort required to complete the task. In contrast, students who prefer the deep approach are motivated by the goal of maximizing their comprehension and constructing meaning by relating the task to their prior knowledge (Entwistle, 2009; Rosário et al., 2010; Rosário, Núñez, Valle, Paiva, & Polydoro, 2013).

Prior knowledge

Students organize knowledge hierarchically, allowing them to

understand new experiences. Severe gaps in prior knowledge of a domain can therefore seriously compromise the acquisition of new knowledge (Alexander, Kulikowich, & Schulze, 1994; Miñano & Castejón, 2011). As a consequence, the level of prior knowledge seems to be a relevant variable to include in this study.

Study time

In general, study time is considered a good predictor of school achievement (Plant, Ericsson, Hill, & Asberg, 2005). Nevertheless, for this to occur, study time and students' corresponding engagement must constantly be adjusted, depending on the students' goals, the nature of the required tasks (e.g., degree of difficulty, perceived utility), and contextual variables (e.g., level of noise, temperature). This may help to explain why the data in the literature do not unequivocally support a direct relationship between study time and school achievement (Gortner-Lahmers & Zulauf, 2000; Núñez, Rosário, Vallejo, & González-Pienda, 2013).

Homework

Despite the long history of research on the role of homework, the strength of the relationship between homework assignment and academic achievement remains inconclusive (Dettmers, Trautwein, & Ludtke, 2009; Rosário et al., 2009; Trautwein & Köller, 2003). Whereas in some studies, a positive relationship was found (e.g., Cooper, Robinson, & Pattal, 2006; Paschal, Weinstein, & Walberg, 1984), others reach less optimistic conclusions, indicating that this relationship is very weak and is mediated by personal, school, and family variables (Ronning, 2011).

Class absence

Finally, in this study, we also considered it important to include the variable class absence, as it has aroused much interest in researchers (Jonanssen, 2011; McIntyre-Bhatty, 2008) due to its association with students' low achievement (Reid, 2006). The study of this variable in connection with other personal or contextual learning variables, for example, those included in this investigation, could provide some clues on how to improve the teaching-learning process.

Contextual variables and academic achievement

Approaches to teaching

Prosser and Trigwell (e.g., Prosser, Trigwell, & Taylor, 1994)

developed a line of research about how teachers teach within the context of higher education. Considering the results derived from their investigations, two different ways of coping with the instructional process (*approaches to teaching*) were identified*:* the Information Transmission/Teacher-Focused (ITTF) approach and the Conceptual Change/Student-Focused (CCSF) approach. Whereas teachers who preferentially adopt an ITTF approach focus their activity on the transmission of information related to the learning contents and on technical issues related to the teaching process, teachers who preferentially use a CCSF approach to teaching are committed to promoting students' engagement in an active process of construction of meaning. Accordingly, those teachers who tend to use the CCSF approach take students' prior knowledge into account and develop teaching strategies to promote the construction of knowledge (Ramsden, Prosser, Trigwell, & Martin, 2007). Research on approaches to teaching was oriented towards the analysis of their relation to contextual variables, for example, class size (Lopes & Santos, 2013; Rosário, Nuñez, Valle, et al., 2013; Singer, 1996; Stes, Gijbels, & Van Petegem, 2008), and to teachers' personal variables, including teacher experience (Prosser, Ramsden, Trigwell, & Martin, 2003; Rosário, Núñez, Valle, et al.,

2013) and teacher gender (Nevgi, Postareff & Lindblom-Ylänne, 2004; Rosário, Núñez, Ferrando, et al., 2013).

Approaches to teaching and class size

The results of research on the relevance of class size to teachers' adoption of a certain approach to teaching in the university context are inconclusive. For example, whereas a study by Singer (1996) found that as class size increases, teachers are more apt to adopt an ITTF approach to teaching, Stes et al. (2008) found no relationship between the CCSF approach and class size. Globally, the results are controversial, as some studies indicate favorable effects associated with the reduction of class size (Pong & Pallas, 2001; Rosário, Núñez Valle, et al., 2013; Rosário, Núñez, Valle, González-Pienda, & Lourenço, 2013) but other studies reach the opposite conclusion (Greenwald, Hedges, & Laine 1996; Konstantopoulos, 2008; Milesi & Gamoran, 2006). As a whole, these results suggest the importance of studying the relationship between the teachers' role in class (e.g., approach to teaching) and class size.

Gender and approaches to teaching

With regard to the relationship between personal teacher

variables and preference for a certain approach to teaching, Lacey, Saleh, and Gorman (1998) found a relationship between gender and approach to teaching, and, as in the study by Nevgi et al. (2004), male teachers were more likely to use the ITTF approach to teaching, whereas females were more likely to use the CCSF approach.

Approaches to teaching and teacher experience

Stes et al. (2008) analyzed the relationship between teacher experience and the CCSF approach, hypothesizing that greater teacher experience would be related to a higher probability of using the CCSF approach. The data provided by this study did not confirm this hypothesis, although the authors advised interpreting these results cautiously because the number of subjects was small (50 teachers from a Belgian university). However, Rosário, Núñez, Ferrando, et al. (2013) obtained evidence that more years of experience were related to greater use of teaching oriented to the construction of knowledge (CCSF).

Parents' educational level and academic achievement

According to the data provided by a large number of empirical studies, parents' educational level is an important predictor of students' behavior in class and of academic achievement (Davis-Kean, 2005; Dearing, McCartney, & Taylor, 2001; Duncan & Brooks-Gunn, 1997; Dubow, Boxer, & Huesmann, 2009). For example, Duncan and Brooks-Gunn concluded that mothers' educational level was significantly related to their children's intellectual achievement even after controlling for some socioeconomic indicators such as the family's economic status. Davis-Kean found a positive relationship between parents' educational level and their expectations for their children, suggesting that parents with higher educational levels actively involve their children in the development of ambitious personal expectations.

Goals of the present study

As mentioned above, thus far, the data provided by the research into the role of the aforementioned student and contextual variables in pre-university students' academic achievement are inconclusive (and even more so in the specific area of Biology). Additionally, there is no relevant information available about the variables considered concurrently in the determination of achievement, nor are there any studies of these variables that consider the results at the individual and class level. Therefore, the

goal of this investigation is to analyze the degree of association between Biology students' academic achievement and certain student variables (approaches to learning, prior knowledge, study time, degree of class absence, homework), teacher variables (approaches to teaching, teacher gender, teacher experience), class size, and parents' educational level.

As the data provided by past research into many of the variables considered herein are inconclusive and the results provided by the reviewed works have not been analyzed from a multilevel perspective, we propose this study from an exploratory perspective. The data analysis strategy seeks answers to the following questions:

a) Do the explanatory variables measured at the class level in this study affect students' achievement in Biology? If so, then which class level variables are relevant to this conditioning? First, we expect that the approach to teaching will be a relevant variable at the class level, such that students' achievement will be better when the teacher's preferred approach to teaching is student-focused (aimed at the construction of meaning), and students' achievement will be poorer when the teacher's approach to teaching is mainly focused on the transmission of information. Second, with regard to the remaining class level variables, we expect that class size will be negatively related with achievement, whereas teacher experience should be positively associated with achievement in Biology.

b) Do the explanatory variables measured at the individual level affect students' achievement in Biology? As before, if the variability explained at the individual level is significant, the predictive value of each of these variables should be determined. Taking prior studies into consideration, we expect that students' greater use of a deep approach to learning (focused on comprehension and acquisition of competence) will be related to higher achievement in Biology and vice versa: greater use of surface learning (interest in acquiring information and meeting criteria of external achievement) will be related to poorer academic achievement in Biology. Although the results of past research have been inconclusive, we also expect study time, class absence, level of prior knowledge of Biology, homework, and parents' educational level to be positively associated with achievement in this academic area.

c) Is there any interaction between the approach to learning (individual level) and the approach to teaching (class level)? Specifically, does the teacher's ap-

proach to teaching moderate the relationship between students' approach to learning and their achievement in Biology?

Method

Participants

Ten high schools situated in the north of Portugal, randomly selected from a total of 45 schools, participated in the study. From these high schools, 57 Biology teachers and their corresponding 988 students in the third year of high school participated. The students presented their parents' authorization to participate in the investigation, and the teachers agreed to participate via e-mail to the main investigator. Of the 988 students, 384 (38.9%) were male, and 604 (61.1%) were female, with ages ranging from 16 to 19 years ($M = 17.2$, $SD = .69$). Of the 57 Biology teachers who participated in the investigation, 11 (19.3%) were male, and 46 (80.7%) were female, with ages ranging from 26 to 61 years ($M = 46.9$, $SD = 9.2$). Their teaching experience ranged from 2 to 36 years ($M = 23.5$, $SD = 9.6$).

Measurement instruments

Student variables

— *Approaches to learning*. The data about approaches to learning were obtained through the Students' Approaches to Learning Inventory (SALI, High School; Rosário, et al., 2007; Rosário, Núñez, Ferrando, et al., 2013). The SALI is made up of 12 items, rated on a 5-point Likert-type scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The confirmatory factor analyses carried out yielded a two-factor structure of the SALI (Rosário, Núñez, Ferrando et al., 2013): surface and deep approaches, with a good fit of the model, χ^2 (49) = 116.64, $p < .001$, $\chi^2/df = 2.38$, GFI = .98, AGFI = .98, CFI = .99, TLI = .98, RMSEA = .03, CI [.02, .03]. The reliability indexes (Cronbach's alpha) were highly satisfactory: $\alpha = .91$ for the deep approach, and $\alpha = .90$ for the surface approach.

— *Class absence*. This variable was assessed at the end of the course by computing the total number of class absences. The information was obtained from the secretariat of the participant high schools ($M = 3.18$, $SD = 4.16$).

— *Study time*. Study time was assessed daily for one week with an open question, which asked the students about the number of hours they dedicated to their personal study. All of the students responded by filling in a diary that was returned to the investigators in a sealed envelope at the end of the week. The

mean study time obtained was 7.47 weekly hours (SD = 5.52).

— *Prior knowledge of Biology*. This variable was assessed by means of the students' grades in high school. In Portugal, grades range between 0 and 20 points, and 10 is the cut-off point to pass. The student body was distributed as follows: a value of 1 was assigned for grades between 10 and 13 (n = 686; 45.6%); a value of 2 was assigned for grades between 14 and 16 (n = 352; 23.4%); and a value of 3 was assigned for grades between 17 and 20 (n = 466; 31.0%).

— *Homework*. At the end of the course, the teachers gave a 1 to all of the students who had completed at least 80% of the assigned homework (41.4%) and a 2 to those who completed more than 80% (58.6%).

Class variables

— *Approaches to teaching*. The data on approaches to teaching were obtained through the Teachers' Approaches to Teaching Inventory (TATI; Rosário, et al., 2007; Rosário, Núñez, Ferrando, et al., 2013). Based on the theoretical framework associated with the models of Prosser and Trigwell (1999) and Ramsden et al. (2007), this instrument has 12 items that provide information about the two approaches to teaching (ITTF and CCSF). As each approach is made up of one motivation and one strategy, the scale also provides data about the two dimensions of each of the approaches. The scale is rated on a 5-point Likert-type scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). By means of a confirmatory factor analysis, we contrasted the theoretical structure of four first-order factors (Motivations and Strategies) and two second-order factors (Approaches). The results showed a good fit of the model: $\chi^2(49)$ = 101.92, p < .001, χ^2/df = 2.08, GFI = .97, AGFI = .95, CFI = .98, RMSEA = .04, CI [(.03, .05], thereby providing evidence of the construct validity of the inventory (Rosário et al., 2010; Rosário, Núñez, Ferrando et al., 2013). With regard to reliability, both factors had adequate levels: α_{ITTF} = .92 and α_{CCSF} = .94.

— *Teaching experience*. The data on teaching experience were obtained from the secretariat of the institutes. The mean number of years of experience was 22.81 (SD = 9.84).

— *Class size*. The information on class size was obtained from the secretariat of the participant high schools.

— *Parents' educational level*. This variable was categorized as follows: 1 (Elementary school), 2 (Compulsory secondary school),

3 (High school), 4 (Licentiate degree), and 5 (Postgraduate). The information was obtained from the secretariat of the participant high schools.

Academic achievement

In order to study toward a Licentiate degree in the area of Sciences (e.g., Chemistry, Medicine, Biology), Portuguese students must take a national Biology exam. To prepare the students for this exam, the Ministry of Education organizes three tests, one each trimester. In the present investigation, the mean of all three Biology tests was calculated and used as the measurement of academic achievement in Biology.

Procedure

The students and teachers were informed of the goals of this investigation. The information was collected during the second semester of the Biology course (between January and April) after obtaining authorization from the directors of the high schools. Participants were instructed to complete the inventories with reference to the subject of Biology.

Data analysis

The hierarchical nature of the data encouraged analysis with a two-level hierarchical model. The statistical modeling process was carried out in four stages. Initially, a random effect ANOVA model, or unconditional model, was formulated, which allows determination of the amount of variance explained at the individual level (Level 1) and the class level (Level 2). Additionally, it serves as referent against which to assess the goodness of fit of more complex conditional models. After performing this first step, the model corresponding to class level was fitted in order to determine the extent to which the contextual instructional variables explain students' achievement. Then, the model corresponding to the individual level was fitted in order to observe the extent to which student variables predict academic achievement in Biology. Finally, we studied the interaction of the two models (individual and class level) in order to estimate the degree of interaction among the variables at the class level and the variables at the individual level.

In all the analyses, the dependent variable was the students' grades obtained at the end of the course as predicted by a set of explanatory variables recorded at the individual level and at the class level. The following variables were measured at Level 1: (a) *approaches to learning*, measured with the SALI scale and dichotomized by a cut-off point as a function of the score obtained

on this scale. Specifically, if the mean score obtained on the subscales associated with the surface approach (Motivation and Strategy) > 9, then the approach to learning = 0; whereas if the mean score obtained on the subscales associated with the deep approach (Motivation and Strategy) > 9,then the approach to learning = 1; (b) *prior achievement*; (c) the degree of completion of *homework* assigned by the teachers: less than 80% = 0, more than 80% = 1; (d) *student gender* : males = 0, females = 1; (e) *study time* (hours dedicated to study) of the subject over the week: minimum = 0, maximum = 25; (f) *class absences* during the school term: minimum = 0, maximum = 20; (g) *parents' educational level*: elementary = 1, ..., postgraduate = 5.

With regard to the explanatory variables recorded at Level 2, we note: (a) the teachers' *approach to teaching,* measured by means of the TATI scale and dichotomized at a cut-off point as a function of the score obtained on the subscales of this scale. Specifically, if the mean score obtained on the subscales associated with teaching focused on transmission of information (Intention and Strategy) > 9, then the approach to teaching = 0; whereas if the mean score on the subscales associated with teaching focused on the construction of knowledge (Intention and Strategy) > 9, then the approach to teaching = 1; (b) *teacher gender*: males = 0, fe-

males = 1; (c) *teacher experience*: minimum = 1, maximum = 36; (d) *class size*: minimum = 8, maximum = 33.

Results

Descriptive statistics

Table 1 presents the descriptive statistics of the Level 1 and Level 2 variables used in this investigation.

Multilevel analysis

Unconditional means model

Data analysis began by fitting the following null or unconditional means model:

$$Y_{ij} = \gamma_{00} + u_{0j} + e_{ij},$$

where Y_{ij} is the achievement observed for the ith student nested in the jth class, γ_{00} is the grand mean (the mean global achievement of the students), u_{0j} represents the variability between classes in terms of students' mean achievement, and e_{ij} represents the variability in the achievement of the students nested in the jth class. It is assumed that the random terms of the model are *NID* (normally and independently distributed) with a mean of zero and constant variance; that is to say, $u_{0j} \sim NID\ (0, \tau_{00})$ and $e_{ij} \sim NIK\ (0, \sigma_e^2)$. Note that it is assumed that the classes studied represent a ran-

Table 1

Descriptive Statistics of the Variables at the Individual and Class Level

	M	SD	Minimum	Maximum
Level 1 Variables (individual)				
Approach to learning	.64	.48	.00	1.00
Prior knowledge	1.85	.85	1.00	3.00
Homework	.61	.49	.00	1.00
Student gender	.61	.48	.00	1.00
Study time	7.79	5.77	.00	25.00
Class absence	3.03	4.19	.00	20.00
Parents' educational level	2.68	1.22	1.00	5.00
Level 2 Variables (class)				
Approach to teaching	.77	.42	.00	1.00
Teacher gender	.80	.40	.00	1.00
Level of teacher experience	23.12	9.99	2.00	36.00
Class size	20.28	4.77	8.00	33.00

Note. Level 1 ($N = 988$); Level 2 ($N = 57$).

dom sample of a certain population, so that the inferences are not exclusive to the sample of students studied.

With this unconditional model, achievement can be explained through a fixed component containing a global value that is the same for all classes and all students, plus a random component indicating the variability associated with the different levels of the analysis, that is: individual level and class level. This preliminary model served as a referent against which to compare the goodness of fit of successive conditional models. In our case, we verified whether the variance components—one representing the variation between class means (τ_{00}) and the other representing the variation among students within classes (σ_e^2)—were significantly different from zero; if this were not the case, there would be no point in analyzing the data at both levels.

Table 2 shows the results obtained after fitting the model to the data in the present investigation. It can be observed that the estimated mean achievement in this sample of classes (13.02) is different from zero ($p < .0001$). However, the most notable result is the existence of statistically significant differences in average achievement levels of students among classes

Table 2

Summary of the Results Obtained with the Unconditional Means Model

Solution for fixed effects					
Effect	Estimator	Standard error	df	*t*-value	Pr > |t|
Intercept	13.0233	.1974	56	65.98	< .0001
Estimators of covariance parameters					
Par Cov	Effect	Estimator	SE	Z-value	Pr > Z
u_{0j}	Classes	1.6100	.4156	3.90	< .0001
e_{ij}	Residual	9.8398	.4560	21.58	< .0001
Fit statistics					
Description	Value				
Deviance	5138.6				
AIC Criterion	5144.2				
BIC Criterion	5150.7				

Note. SE = standard error; df = degrees of freedom; Deviance = minus twice the logarithm of the maximum similarity function; AIC = Akaikes' information criterion; BIC = Bayesian information criterion.

(u_{0j} = 1.61; p < .0001) and in their achievement levels within classes (e_{ij} = 9.84; p < .0001). In 95% of the cases, the magnitude of the variation among classes in mean achievement levels was expected to fall within the interval [10.45, 15.56]. This indicates a moderate range of variability in average achievement levels among classes in this sample of data. Further, the observed variability in academic achievement (1.62 + 9.84 = 11.46) is mainly due to the Level 1 variables: 85.9% of the variability is due to individual level variables, and the remaining 14.4% is due to class level variables (achievement is higher in some classes than in others).

The degree of dependence among the students' observations within the same class, approximately .141 in our case, contradicts the hypothesis of independence assumed by the classic regression model, arguing for data analysis at two levels (individual and class).

Models with class level predictors

The unconditional means model does not consider either student or class characteristics; it

merely provides a basis for comparison against more complex models. However, achievement could be explained by the characteristics of the students who make up the classes, the characteristics of each class, as well as the combined effect of both. We sought to understand why mean achievement is higher in some classes than in others. To explain this, we carried out a new analysis, incorporating the explanatory variables recorded at the class level, Level 2 (the approach to teaching, teacher gender, class size, and teacher experience), paying particular attention to teaching approach.

Specifically, at Level 2, the following conditional model was formulated:

$$Y_{ij} = \gamma_{00} + \gamma_{01} \text{ (teaching approach)}_j +$$
$$\gamma_{02} \text{ (gender)}_j +$$
$$\gamma_{03} \text{ (class size)} +$$
$$\gamma_{04} \text{ (teacher experience)}_j + u_{0j} + e_{ij}.$$

where Y_{ij} represents the achievement observed for the ith student nested in the jth class, γ_{00} represents the mean achievement of the students instructed by teachers of average experience in average sized groups, γ_{01} indicates whether the achievement of students instructed with methods mainly focused on the teacher (approach to teaching focused on information transmission, ITTF) differs from the achievement of students instructed with methods mainly focused on the student (approach to teaching focused on students' construction of knowledge, CCSF), while controlling for the effects of the variables teacher gender, class size, and teacher experience; γ_{02} indicates whether the achievement of students instructed by women differs from that of students instructed by men, while controlling for the effects of the variables approach to teaching, class size, and teacher experience; γ_{03} represents the change in students' mean achievement for each unit of increase in class size, controlling for the effects of the variables approach to teaching, teacher gender, and teacher experience; γ_{04} represents the change in students' mean achievement as a consequence of the increase in teacher experience, controlling for the effects of the variables approach to teaching, teacher gender, and class size. Finally, u_{0j} represents the variation in class means in academic achievement, and e_{ij} represents the within-class variation.

The results of fitting both conditional random intercept models with Level 2 predictors are shown in Table 3. According to the first of the two fitted models (Model A), there is no evidence of a statistically significant change in the students' mean achievement as a function of the instruction method employed (approach to teaching), teacher gender, class size, or teacher experience. Note that this changes slightly when fitting a more parsimonious conditional model (Model B in Table 2) be-

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Table 3

Summary of the Results Obtained with the Random Intercept Conditional Model with multiple Level 2 Predictors

	Model A			Model B		
	Fixed effects					
Effect	Estimator (SE)	df	Pr > |t|	Estimator (SE)	df	Pr > |t|
Intercept	13.162 (1.02)	52	<.0001	12.31(0.41)	55	<.0001
Approach to teaching	.724(0.47)	52	.131	.91(0.46)	55	.054
Teacher gender	−.037(0.49)	52	.940			
Class size	−.052(0.04)	52	.200			
Teacher experience	.015(0.02)	52	.459			
	Random effects					
Par Cov	Estimator (SE)	Z	Pr > Z	Estimator (SE)	Z	Pr > Z
u_{0k}	1.38(0.37)	3.68	<.0001	1.46(0.39)	3.75	<.0001
e_{ij}	9.85(0.46)	21.56	<.0001	9.84(0.45)	21.57	<.0001
	Fit statistics					
Description	Value			Value		
Deviance	5132.9			5134.9		
AIC Criterion	5146.9			5142.9		
BIC Criterion	5162.2			5151.1		

Note. SE = standard error; df = degrees of freedom; Deviance = minus twice the logarithm of the maximum similarity function; AIC = Akaikes' information criterion; BIC = Bayesian information criterion.

cause the difference between the intercept values of each model is small (13.16 − 12.31 = .85). However, with the reduced model (Model B), a marginally nonsignificant relationship between the teachers' approach to teaching and the students' mean achievement is observed (γ_{01} = .907, *p* = .055). But examination of the variance corresponding to Level 2 shows that this relationship does not change significantly when incorporating the variable approach to teaching at class level; specifically, the unconditional variance was 1.61, and the conditional variance was 1.46. This indicates that approximately 10% of the variability observed in mean achievement is explained by the approach to teaching. We also observe that the conditional or residual intraclass correlation only decreases by two hundredths

after controlling for the effect of the variable teachers' approach to teaching, dropping from .14 to .12 (1.46/11.31 = .12).

Although Model B does not allow us, in statistical terms, to conclude that the teachers' approach to teaching affects student achievement, this variable was not removed from the analysis because it was marginally nonsignificant ($p = .055$) and central to the present investigation. Moreover, it is noted that Model B, with smaller information criteria—AIC and BIC in our case—is the model that best fits the data. We would have reached the same conclusion if we had used the AIC based on conditional likelihood instead of the AIC based on marginal likelihood; DIC (Deviance Information Criterion) is routinely used for Bayesian model comparison (see Vallejo, Tuero, Núñez, & Rosário, in press).

Models with individual level predictors

The previously fitted model only considers the effect of the variables of class composition and context; it does not consider the students' characteristics. The reasons for the differences in students' achievement is therefore unknown, and there is no evidence that the between-classes variability observed is not an artifact due to the different profiles of the students who are instructed by the teach-ers in each class. To clarify to this issue, we performed a new analysis with seven individual-level variables: *prior achievement*, *doing homework*, *student gender*, *approach to learning*, *parents' educational level*, *study time,* and *class absence,* with the latter two variables centered around the group mean. Initially, we performed a test to verify the random variation of the slopes one by one, observing that they remained constant except for the slope corresponding to the factor approaches to learning, which varied across classes.

The resulting model of random coefficients can be expressed as follows:

$$
\begin{aligned}
Y_{ij} = {} & \gamma_{00} + \gamma_{10} \, (study\ time)_{ij} + \\
& \gamma_{20} \, (prior\ knowledge)_{ij} + \\
& \gamma_{30} \, (homework)_{ij} + \\
& \gamma_{40} \, (absence)_{ij} + \gamma_{50} \, (gender)_{ij} + \\
& \gamma_{60} \, (parent\ education)_{ij} + \\
& \gamma_{70} \, (learning\ approach)_{ij} + u_{0j} + \\
& u_{1j} \, (learning\ approach\,)_{ij} + e_{ij}
\end{aligned}
$$

where Y_{ij} represents the achievement observed for the ith student nested in the jth class, γ_{00} represents the students' mean achievement, γ_{10} represents the change in students' mean achievement for each unit of increase in hours of study time, controlling for the effects of the remaining variables; γ_{20} indicates the relationship between prior knowledge and achievement, controlling for the effects of the remaining variables; γ_{30} indicates the relation-

ship between doing homework and achievement, controlling for the effects of the remaining variables; γ_{40} represents the change in students' mean achievement for each unit of increase in class absence, controlling for the effects of the remaining variables; γ_{50} indicates the relationship between students' gender and their achievement, controlling for the effects of the remaining variables; γ_{60} indicates the relationship between the parents' educational level and their children's achievement, controlling for the effects of the remaining variables; and γ_{70} indicates how the approach to learning affects achievement, controlling for the effects of the remaining variables. Finally, u_{1j} indicates whether the relationship between the approaches to learning and mean achievement varies across classes.

Table 4 shows the most relevant results obtained after fitting both random coefficient models. According to Model A, there is no evidence of changes in mean achievement as a function of hours of study time over the week ($p = .074$). It is interesting to note that there is a statistically significant relationship between the variables study time and achievement when not controlling for the effect of the variable approaches to learning used by the students; nevertheless, as observed in Table 4, this relationship is marginally nonsignificant when controlling for the effect of approaches to learn-

ing. Moreover, there were no statistically significant gender differences in the students' achievement ($p = .389$). We could not reject the null hypothesis of an absence of association between the variable degree of completing homework assigned by the teachers and the variable achievement ($p = .431$).

Finally, the results in Table 4 for Model A also show that the relationship between students' approach to learning and mean within-class achievement varied significantly across classes ($u_{1j} = .948$, $p = .015$). However, there is no evidence that the effects of approaches to learning on students' academic achievement differ depending upon the average level of academic achievement in the class. In our study, the covariance slope and intercept across classes were not statistically significant ($p = .227$).

The above results indicate the appropriateness of fitting a simpler model, for example, one in which the intercept and slope are allowed to vary across classes, and eliminating the explanatory variables that were nonsignificant in the previous step; in other words, a simpler model, Model B, may provide a reasonable fit to the data. This statement can be easily verified by examining the fit statistics in Table 4; note that we are seeking models with the lowest values in the AIC and BIC criteria. As Model A does not explain the data better than Model B, and Model B

Table 4

Summary of the Results Obtained with the Random Intercept and Slope Models and with Multiple Level 1 Predictors

	Model A			Model B		
	Fixed effects					
Effect	Estimator (SE)	df	Pr > |t|	Estimator (SE)	df	Pr > |t|
Intercept	9.846(.477)	56	<.0001	9.779(.446)	56	<.0001
Study time	.029(.020)	924	.0736			
Prior knowledge	.692(.182)	924	.0001	.745(.179)	927	<.0001
Homework	.904(1.147)	924	.4311			
Class absence	−.105(.024)	924	<.0001	−.109(.024)	927	<.0001
Student gender	−.985(1.143)	924	.3891			
Parents' educational level	.356(.086)	924	.0001	.372(.086)	927	<.0001
Approaches to learning	1.746(.297)	924	<.0001	1.821(.258)	927	<.0001
	Random effects					
Par Cov	Estimator (SE)	Z	Pr > Z	Estimator (SE)	Z	Pr > Z
u_{0j}	1.128(.506)	2.23	.0130	.677(.288)	2.35	0094
u_{1j}	1.833(.857)	2.14	.0162	.984(.459)	2.17	0151
u_{01}	−.720(.561)	−1.28	.2268			
e_{ij}	8.218(.447)	21.05	<.0001	8.343(.394)	21.19	<.0001
	Fit statistics					
Description	Value			Value		
Deviance	4975.5			4980.1		
AIC Criterion	4999.5			4996.1		
BIC Criterion	5024.0			5012.4		

Note. SE = standard error; df = degrees of freedom; Deviance = minus twice the logarithm of the maximum similarity function; AIC = Akaikes' information criterion; BIC = Bayesian information criterion.

is more parsimonious, we chose the latter model.

First, note that after fitting the Model B, there is on average a statistically significant relationship between students' approaches to learning and their academic achievement (γ_{70} = 1.821, p < .0001) within classes. More specifically, taking the direction of the association into account, the results indicate that the achievements of students who usually use a deep approach to learning were significantly higher than those of students who usually use a sur-

face approach. We also verified that prior knowledge positively and significantly predicted present academic achievement ($\gamma_{20} = .745$, $p < .0001$). Further, we found that both class absence and parents' educational level significantly affected the participants' achievement ($\gamma_{40} = -.109$, $p < .0001$ and $\gamma_{60} = .372$, $p < .0001$, respectively); however, whereas the former reduced achievement, the latter increased it. Finally, the variance components (within and between classes) remain significantly different from zero ($e_{ij} = 8.343$, $p < .0001$; $u_{0j} = .667$, $p = .009$). It is therefore very important to continue to investigate other causes not taken into account in this analysis that might —at least partially— explain these variabilities. Nevertheless, in this case, not only did the within-class variance decrease from 9.848 to 8.343, but the between-class variance also dropped from 1.385 to .677.

Models with individual and class level predictors

After separately fitting a model for individual level variables and another for class level variables, we will consider a model that includes variables at both levels. This model will allow us to detect the possible existence of crossed interactions between the levels.

Combining the models fitted at the student and at the class level, the following equation is obtained:

$$
\begin{aligned}
Y_{ij} = {} & \gamma_{00} + \gamma_{01} \, (teaching\ approach)_j + \\
& \gamma_{10} \, (prior\ knowledge)_{ij} + \\
& \gamma_{20} \, (class\ absence)_{ij} + \\
& \gamma_{30} \, (parent\ education)_{ij} + \\
& \gamma_{40} \, (learning\ approach)_{ij} + \\
& \gamma_{11} \, (teaching\ approach)_{ij} \times \\
& (learning\ approach)_{ij} + u_{0j} + \\
& u_{1j} \, (learning\ approach)_{ij} + e_{ij}
\end{aligned}
$$

This reveals that achievement can be considered as a function of fixed effects plus random effects. The fixed effects are: general mean (γ_{00}), main effect of the approach to teaching (γ_{01}), main effect of prior achievement (γ_{10}), main effect of class absence (γ_{20}), main effect of parents' educational level (γ_{30}), main effect of approach to learning (γ_{40}), and crossed interaction between approaches to teaching and approaches to learning (γ_{11}). The random effects represent the between-class variability (u_{0j}) among the approaches to learning across the classes (u_{1j}) and within classes (e_{ij}) As all of the issues that motivated this analysis have been specified except for the one referring to crossed interaction, we estimated (γ_{11}) to examine whether the teacher-focused approach to teaching (information transmission) differs from the student-focused approach to teaching (facilitating students' construction of knowledge) in terms of the strength of the association between approaches to teaching and students' academic achievement.

Table 5

Summary of the Results Obtained with the Random Intercept Combined Model

Fixed effects					
Effect	Estimator	(SE)	Df	*t*-Value	Pr > |*t*|
Intercept	9.424	(.516)	55	18.28	<.0001
Approach to teaching	.673	(.432)	55	1.56	.1248
Prior knowledge	.694	(.178)	926	3.90	<.0001
Class absence	−.108	(.024)	926	−4.49	<.0001
Parents' educational level	.374	(.086)	926	4.36	<.0001
Approach to learning	2.884	(.526)	926	5.49	<.0001
Approach to teaching × Approach to learning	−1.403	(.594)	926	−2.37	.0184

Random effects					
Par Cov	Effect	Estimator	SE	Z-value	Pr > Z
u_{0j}	Classes	.658	.267	2.30	.0108
u_{1j}	Approach to learning	.867	.431	2.01	.0222
e_{ij}	Residual	8.319	.392	21.25	<.0001

Fit statistics	
Description	Value
Deviance	4974.3
AIC Criterion	4994.3
BIC Criterion	5014.8

Note. SE = standard error; df = degrees of freedom; Deviance = minus twice the logarithm of the maximum similarity function; AIC = Akaikes' information criterion; BIC = Bayesian information criterion.

Table 5 presents the most important results obtained after fitting the model that includes Level 1 and Level 2 predictors. Specifically, we verified that the teachers' approach to teaching had no statistically significant main effects ($\gamma_{01} = .673$, $p = .125$), although it had a secondary effect through its interaction with students' approaches to learning ($\gamma_{11} = −1.403$, $p = .018$).

Nevertheless, the achievement of students instructed by teachers preferentially using a student-focused approach to teaching was slightly better (10.10) than that of students instructed by teachers preferentially using a teacher-focused approach to teaching (9.42). With regard to the interaction, the strength of the association between the students' approaches to learn-

ing and their achievement in Biology varied depending on whether the teachers regularly used a student-focused approach or a teacher-focused approach to teaching. In other words, due to the moderating effect of the teachers' approach to teaching, the differences in the achievement of students who preferentially used a deep approach were higher than that of students who used a surface approach when the teachers preferentially used a student-focused approach instead of a teacher-focused approach.

Finally, the components of intercept and slope variance remained statistically significant ($p = .011$ and $p = .022$, respectively), indicating a significant between-class variation in both coefficients. The addition of the variable approach to teaching and its crossed interaction with approach to learning slightly reduced the residual variance of the intercept ($\approx 3\%$) and the residual variance of the slope for approaches to learning ($\approx 13\%$) in comparison with the estimated variance for the random coefficient model of the previous section. Nevertheless, rejection of the null hypothesis would indicate that there is additional variation in class mean achievement levels that is not explained by the variables included in the model. It is foreseeable that the inclusion of additional class-level variables would further reduce the variance corresponding to the classes. Therefore, additional

student and teacher characteristics not taken into account in this analysis might explain this variation.

Discussion

The goal of this investigation was to analyze the degree to which academic achievement in Biology of students in the last year of high school is predicted by certain student variables (i.e., approaches to learning, prior knowledge, study time, class absence, homework), teacher variables (i.e., approaches to teaching, gender, teacher experience), and contextual variables (i.e., class size, parents' educational level). As the data show a hierarchical structure (students nested within classes), a multilevel strategy was conducted. By means of this type of analysis, this study not only allowed us to determine the relevance of individual-level and class-level variables in the prediction of achievement in Biology, but also to study the interaction of the variables of both levels, an aspect that has received little attention in past research but is of great theoretical and applied importance.

In general, whereas the hypotheses formulated at the class level were mainly not confirmed, the hypotheses at the individual level were confirmed to a great extent. Thus, we confirmed that most of the variability in Biology achievement was associated with individual-level variables (85.6%),

whereas the class-level variables only explained 14.4% of the variability. However, the data corresponding to the interaction between the teachers' way of teaching and students' way of learning and academic achievement were particularly relevant. Below, the most important findings are discussed.

Individual-level analysis

With regard to the variables analyzed at individual level (Level 1), prior knowledge of the subject, class absence, parents' educational level, and approach to learning were good predictors of achievement in Biology, and the last variable was the most relevant in this equation. Study time, the amount of homework done, and student gender had no significant main effects.

With regard to the significant effects, as expected, a higher level of prior knowledge was related to better achievement in Biology. Likewise, we observed that greater class absence was related to poorer academic achievement (Reid, 2006). In keeping with some previous research, in this study, we found that parents' higher educational level was associated with their children's higher Biology achievement (Davis-Kean, 2005; Dubow et al., 2009). Lastly, this investigation provides clear evidence that greater use of a deep approach to study leads to higher achievement and that use of a

more superficial approach to learning is related to poorer achievement in Biology. Although some works have expressed doubts about this relationship (Entwistle, 1991; Rosário et al., 2010; Struyven, Dochy, Janssens, & Gielen, 2006), the data presented in the current study clearly show that the benefits come from the use of a deep approach, implying intrinsic or task-oriented motivation and the use of cognitive and metacognitive strategies to comprehend and elaborate the information.

With regard to the nonsignificant variables in the explanation of achievement in Biology (study time, student gender, and amount of homework done), the students study time on Biology deserves special mention. Specifically, although this variable was not relevant when all of the student variables were included in the equation, its main effect becomes significant if the variables that were significant (prior knowledge, class absence, parents' educational level, and approaches to study) are eliminated from the equation. Thus, study time is an important variable, but when including other variables such as approaches to learning the effect of study time occurs through the latter (in fact, studying with a deep approach to learning involves more study time than studying with a surface approach). With regard to the other two variables, our data indicate that doing more or less homework does not explain a sig-

nificant amount of the variability in achievement. How can we explain these data? On the one hand, error estimation was high (1.137), perhaps due to the dichotomization of the homework variable, (which also occurs with the error estimation of gender, 1.134). On the other hand, as in the case of study time, the effect of the amount of homework done could also be subsumed by the students' approach to learning (it is possible that doing homework with a deep approach could involve completing more homework tasks and spending more time compared to completing homework using a surface approach). Therefore, like study time, the amount of homework may play a more important role than the one suggested by the results of the analysis when all of the variables are present. Future research should analyze this hypothesis in depth (measuring homework as a continuous variable) while considering it as a class-level variable.

Class-level analysis

None of the variables included in the equation at class level showed significant main effects. Only the approaches to teaching showed a mild main effect on achievement in Biology at this level of analysis ($p < .10$), although this limited effect dissipated when the approach to teaching was related to the approach to studying.

Interaction between approaches to teaching and approaches to learning

This study provides relevant and novel information about the interaction between students' approaches to learning (Level 1) and teachers' approaches teaching (Level 2). As mentioned, the results at the individual level indicated that students who preferentially use a deep approach to studying perform better, and students who are more likely to use a surface approach show poorer achievement. When taking into account both levels of analysis, we confirmed that this difference in achievement was greater in the students instructed by teachers whose approach to teaching was mainly focused on transmitting information (ITTF) than in the students whose teachers used an approach to teaching preferentially oriented to helping the student to construct meaning (development of processes of comprehension and elaboration of the information, CCSF). What could be the reason for this finding? Students' learning and achievement may be significantly more determined by their personal characteristics considered herein (e.g., study time, homework completion) and by other characteristics not considered (e.g., students self-set goals, attitude towards learning) than by their teachers' ITTF approaches to teaching.

On the other hand, when a teacher promotes instructional contexts that demand students' active and significant involvement in the construction of knowledge (CCSF), students who are more likely to use a surface approach to learning will be encouraged to use a deeper approach to learning because a surface approach will not be useful in this teaching context.

Limitations of the study

The present investigation has involved a great effort to collect sufficient data from students, parents, and teachers in order to carry out the analysis from a multilevel perspective. However, there are some aspects of the study that could modulate the interpretation of the results obtained. First, the fact that information about approaches to learning and teaching was obtained by means of self-report instruments means that such information is based on what the students and teachers think they do in their respective tasks. Although the use of self-report measures is very common in research in the field of education, it is still a limitation because the results should be interpreted as what teachers and students think they do and not what really occurs. Second, the conclusions derived from this study may not be completely transferable to other academic disciplines or to students of other ages (Stes et al., 2008). It would therefore be interesting for future research to explore the many questions that persist in this area.

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