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Acceptance of evolutionary theory among pre-service teacher students and in-service teachers in Ecuador

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Abstract

Background Despite its prominent role in contemporary biology and science, the theory of evolution is still contested by many social groups, showing a deficient understanding of its central postulates and low acceptance rates in many countries. A region traditionally understudied in this respect is Latin America. Within this region, Ecuador stands out as a key territory in the history of evolutionary thought, given the importance of the Galápagos fauna to the eventual realization of the fact of evolution by Charles Darwin. In the present study, we investigate the acceptance of the theory of evolution in a heterogeneous sample of pre-service teacher students (enrolled in formal education programs for teaching certification) from the Sierra region and in-service teachers (participating in professional development) from the Amazonia and Galápagos Islands regions. To gain insights into the potential causes of acceptance of evolutionary theory (MATE instrument), a series of sociodemographic variables, as well as measures of knowledge of evolution (KEE) and religiosity (DUREL) were also taken.

Results Our results show low values of acceptance (MATE = 67.5 out of 100), a very low level of knowledge (KEE = 3.1 out of 10), and moderate religiosity (DUREL = 3.2 out of 5). The relationship between variables was complex, but two of them showed a trend: knowledge and religiosity affect positively and negatively, respectively, the acceptance of evolutionary theory, although this influence is only moderate and varies between regions.

Conclusions A series of potential explanations for this trend are discussed in light of the religious and educational differences of each region.

Keywords Evolutionary knowledge, KEE, Acceptance of evolutionary theory, MATE, Religiosity, DUREL

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Background

The theory of evolution stands as one of the most significant scientific theories shaping our civilization (Coyne 2009; Dobzhansky 1973; Stamos 2008). It constitutes the cornerstone of our understanding of biology and provides valuable insights across various other disciplines, such as psychology, medicine, philosophy, and numerous social sciences (Buss 2015; Dennett 1995; Perlman 2013; Rosenberg 2000; Ruse 1985). Despite its pivotal role, this theory has faced resistance, if not outright hostility, from certain segments of society (Barnes 2020; Miller et al. 2006; Thagard and Findlay 2009). This resistance is expressed in a lack of acceptance of the theory's main postulates and validity; a rejection with profound consequences for the perception of our interconnectedness with other life forms, or our place as humans in the grand scheme of things (e.g., Coyne 2009; Dawkins 1996; Wilson 1998;).

From the point of view of psychology and education, the evolutionary theory's acceptance level in our societies is often assessed using the concept of "evolutionary acceptance," which has been defined in various ways (e.g., Barnes et al. 2024). A consensus definition, however, can be "agreeing that evolution is valid, and the best explanation from science for the unity and diversity of life on earth, which includes speciation, the common ancestry of life, and that humans evolved from non-human ancestors" (Barnes et al. 2024). Studies assessing evolutionary acceptance have been conducted since the seminal work of Miller et al. (2006) to more recent investigations (Gefaell et al. 2020; Kuschmierz et al. 2021; Manwaring et al. 2018; Oliveira et al. 2022; Zappala et al. 2023; Zhu and Weisberg 2020), consistently revealing significant disparities among social groups and countries, even those with similar economic or cultural backgrounds. For instance, recent studies have highlighted substantial variation in evolutionary acceptance levels across European countries, regardless of the specific groups studied or the measurement methods employed (Kuchsmierz et al. 2020, 2021). For example, evolutionary acceptance in in-service teachers ranged from moderate in Turkey through high in Britain, up to very high in Greece (using the qualitative classes defined by Kuschmierz et al. 2020). In general, individuals from particular religious' denominations show typically lower acceptance levels than equivalent non-religious or not-identified religious individuals (Kuschmierz et al. 2020).

This variability among countries and social groups has been attributed to several factors, which are not mutually exclusive: (1) Differences in evolutionary knowledge (Weisberg et al. 2018), (2) Variations in understanding of the nature of science (NOS; Fiedler et al. 2018; Lombrozo et al. 2008; Mead et al. 2018), (3) individual economic prosperity (Heddy and Nadelson 2012), and (4) negative influence from religious beliefs (Barnes et al. 2019; McComas 2017; Rissler et al. 2014). Among these, the last has garnered the most attention, with some studies highlighting a significant negative correlation between religiosity and acceptance of evolution (Heddy and Nadelson 2012; Miller et al. 2006; Rissler et al. 2014; Salazar-Enriquez et al. 2023), and others diminishing its importance (Mead et al. 2018; Oliveira et al. 2022). For instance, it has been claimed that religious hostility against evolution could reduce the efficacy of evolution education (Manwaring et al. 2018; but see Weisberg et al. 2018). Furthermore, a global internet-based survey revealed that nearly 60% of Christians adhere to creationist views, with European Christians being a notable exception (Wilson 2010).

Beyond religion, though, recent research suggests that socio-cultural and political factors may also influence evolutionary acceptance in some countries (Zhu et al. 2020; Oliveira et al. 2022). Generally, European countries exhibit moderate to very high levels of evolutionary acceptance among school students (elementary, middle, and high school levels), pre-service teachers, and university students. This acceptance tends to increase positively with higher levels of education (Kurschmierz et al. 2020; Mantelas and Mavrikaki (2020); reviewed in Kurschmierz et al. 2021). The situation, however, is less favorable in other regions (Miller et al. 2006). Studies indicate that acceptance of evolution among citizens is notably low in Russia, while moderate rates are observed in countries such as South Korea, India, and China, among others (Pobiner 2016).

Although some research exists, Latin America, spanning from Mexico to Chile, has been one of the less extensively studied geographical areas, with comparatively few studies conducted (see Nunez et al. 2012; Tavares and Bobrowski 2018). This situation, though, is starting to change. For example, recently Oliveira and colleagues (2022) conducted a comparative study on evolutionary acceptance among high school students in Italy and Brazil. They found lower levels of acceptance and knowledge in Brazil compared to Italy, attributing this difference primarily to variations in economic and sociocultural factors rather than differences in religiosity. A study involving undergraduate students from Colombia revealed moderate acceptance of evolution, with no significant differences in evolutionary knowledge observed between STEM (science, technology, engineering, and mathematics) and non-STEM degrees (Archila et al. 2023). Salazar-Enriquez et al. (2023) reported moderate to high acceptance of evolution among high school students in Mexico, with religiosity identified as one of the main negative influencing factors. Similarly, Zappala and coworkers (2023) found that supernatural beliefs and dualistic thinking negatively affect evolutionary knowledge in Argentinian psychology and medicine students. Lastly, Pobiner (2016) refers to a survey by the Pew Research Center on 19 South American countries, indicating that most citizens, especially Protestants, perceive a fundamental tension between religion and evolutionary concepts. In summary, Latin American countries tend to show moderate levels of evolution acceptance but face potential conflicts between religion and evolution. Even in the Galápagos Islands (Ecuador), whose fauna was pivotal to Darwin's realization of the fact of evolution (Bowler 2009), biology teachers' enthusiasm for the idea of evolution is not accompanied by a clear knowledge of evolution or an acceptance of certain evolutionary principles (Cotner et al. 2016). Beyond the Galápagos Islands, however, no study has yet assessed evolutionary acceptance in the different geographic regions that make up modern Ecuador.

Ecuador spans approximately 250,000 km^2 with a population of around 17 million inhabitants, situated in the northwest of South America (INEC 2022). The country comprises four distinct regions–Costa, Sierra, Amazonia, and Galápagos– each characterized by significant cultural, ethnic, climatic, and geological diversity, contributing to the richness of this nation (Carrión-Mero et al. 2022). The majority of Ecuador's population resides in urban areas (63.1%), with the remaining (36.9%) living in rural zones (INEC 2022). Distribution across the regions varies, with 53.3% in Costa, 41% in Sierra, 5.5% in Amazonia, and 0.2% in Galápagos. In terms of ethnic composition, the population identifies primarily as *Mestizo* (77.5%), Indigenous (7.7%), Montubia (7.7%; indigenous to Costa), Afro-Ecuadorian (4.8%), and a small percentage classified as *Other* (2.8%; of European origin, Mulato and others; INEC 2022). Most of Ecuador's population (91.95%) identifies with a religious affiliation (Goulard 2012; Yánez 2018). Among these, Catholicism is the predominant faith, accounting for 80.4%, followed by Evangelical (11.3%), Jehovah's Witnesses (1.29%), and the remaining categorized as *Other* (6.96%; including Christians, Jews, Muslims, etc.). Still in many indigenous communities, the new religions have been integrated with ancestral beliefs (Goulard 2012; Yañez 2018). Educational schedules also differ across these regions, with Costa and Galápagos following a teaching period from May to February, while the other two regions operate from September to June.

The current regulations for Elementary and Secondary Education in Ecuador is the Prioritized curriculum with emphasis on communication, mathematics, digital, and socio-emotional skills (Ministry of Education 2021). It is organized by areas of knowledge: Language and Literature, Mathematics, Natural Sciences, Social Sciences, Foreign Language, Physical Education, and Cultural and Artistic Education. The theory of evolution is included in compulsory education, in the last sublevel of Primary Education. In Secondary Education, the theory becomes one of the main axes of the curricular elements.

The analysis of the curriculum's content shows many of the core ideas needed for understanding evolution (Lehrer and Schauble 2012; Vázquez-Ben and Bugallo 2018): biodiversity, variation, natural selection, adaptation, inheritance, common ancestor, and change. Almost all core ideas are worked on at the last sublevel of Primary and throughout Secondary Education. In previous sublevels, they only deal with the core ideas of adaptation and biodiversity, focusing exclusively on plants and animals. Although specialists highlight the importance of starting the teaching of evolution early (Nelson 2012; Campos and Sá-Pinto 2013; Lehrer and Schauble 2012; Pobiner 2016; Frejd et al. 2022), Ecuadorian regulations lack this progression.

Taking these factors into consideration, here we describe a study aimed at exploring the levels of evolutionary acceptance among pre-service teacher students and in-service teachers across various regions of Ecuador. For this, we used several demographic and sociopsychological variables (including knowledge of evolutionary theory and religiosity) as predictors. One advantage of conducting this study is the country's high percentage of religious practitioners and presumed moderate to high level of religiosity (ideal for checking the explanatory importance of this factor), coupled with the presence of different religions that may hold varying attitudes towards evolution, dispersed across different geographical areas (Petkova 2015). More specifically, our study intends to assess the levels of acceptance of evolutionary theory among pre-service teacher students from the Sierra region and in- service teachers from the Amazonia and Galápagos regions. This comparative analysis allows us to examine the influence of religiosity in two regions characterized by similarly high levels of religious adherence but influenced by different social factors. Although the data was collected without specific hypotheses in mind (i.e., with the study being mostly exploratory), we expected to find patterns between the degree of religiosity and evolution acceptance.

Methods

Overview

We administered several anonymous online questionnaires in Spanish (the main official language in Ecuador) including demographic, evolutionary acceptance, evolutionary knowledge, and religiosity questions to last year's pre-service teacher students from the *Sierra* region ($N = 374$) on 11th May 2023. Their degrees included *Basic Education* (EB), *Initial Education* (EI), *Bilingual Intercultural Education* (EIB), *Special Education* (EE), *Education in Experimental Sciences* (ECE), *Pedagogy of the Arts and*

Humanities (PAH), and *Pedagogy of National and Foreigner Languages* (PINE; all acronyms correspond to their initials in Spanish). Of these, only two (PAH and PINE) do not incorporate natural sciences in their curriculum. Additionally, we administered these same questionnaires to in-service teachers from *Amazonia* ($N = 705$; 29th October 2022) and Galápagos ($N = 201$; 6th June 2023). There are some differences in the characteristics of in-service teachers between these regions; in the Amazonia region, individuals may be allowed to teach without formal degrees due to the difficulty of recruiting educators in such remote areas. Conversely, in the Galápagos region, teachers typically hold formal degrees, resulting in a higher proportion of educators with at least a degree (82.6%) compared to the Amazonia region (1.3%; see Table 1). Data were collected using the academic infrastructure of the National University of Education of Ecuador (UNAE) in the Amazonia and Sierra regions. In the case of the Galápagos Islands, data were collected in collaboration with Galápagos Conservancy, the Scalesia Foundation, and the Ecuador's Ministry of Education. Due to logistic difficulties, no data was collected in the fourth Ecuador region, Costa. Data collection procedures and quality controls were based on those described in Gefaell et al. (2020).

Data collection

The questionnaires were completed by a total of 1,346 individuals, each using a Google Form tailored to their respective class, accessed via their mobile devices, and overseen by at least one co-author of the manuscript. In the Sierra and Amazonia regions, the questionnaires were administered within the centers network of the National University of Education of Ecuador (UNAE), located at Cañar (UNAE headquarters), Zamora Chinchipe, Morona Santiago, Pastaza, Orellana, Napo, and Sucumbíos provinces (see Fig. 1). In the Galápagos region, the questionnaires were conducted in Santa Cruz, San Cristobal and Isabela through the "Education for Sustainability" teacher training program offered by Galápagos Conservancy, the Scalesia Foundation, and Ecuador's Ministry of Education. Subsequently, some questionnaires were excluded from analysis due to either exceeding the allotted 15-minute time limit for completion or incomplete responses to the MATE questionnaire. Ultimately, statistical analysis was conducted on data extracted from 1,280 participants.

Ethics statement

All data were obtained in accordance with the ethical principles expressed in the Belmont Report and Declaration of Helsinki and with the approval of the Ethics Committee of the National University of Education of Ecuador (UNAE) (REF: CE-SE-001-No.-001-2024-UNAE).

Demographic variables

The demographic questionnaire section requested the following information: *Gender* (Male, Female, or Other), *Age*, *Ethnicity* (Mestizo, Indigenous, Montubio, Afro-Ecuadorian, European, or Mulato), *Indigenous Nationality* (A'I Cofán, Achuar, Kichwa, Shuar, Secoya, Tsa'chila, Zápara, unspecified), *Province of Birth* (Azuay, Bolívar, Cañar, Carchi, Chimborazo, Cotopaxi, El Oro, Esmeraldas, Galápagos, Guayas, Imbabura, Loja, Los Ríos, Manabí, Morona Santiago, Napo, Orellana, Pastaza, Pichincha, Santa Elena, Santo Domingo, Sucumbíos, Tungurahua, and Zamora Chinchipe), and *Education* (Basic General Education, Technical Bachelor, Bachelor, Technology, Degree, and Master). This later variable was numerically recodified in order to be analysed semi-quantitatively (BGE = 1 < Bachelor + Technical Bachelor = 2 < Technology = 3 < Degree = 4 < Máster = 5). Each of these levels represents different academic achievements, so the variable can be considered ordinal.

Instruments to measure acceptance, knowledge, and religiosity

Various questionnaires have been developed to estimate evolutionary theory acceptance (reviewed by Barnes et al. 2024; Beniermann et al. 2022;). Among these, the most widely used tool is MATE (*Measure of Acceptance of the Theory of Evolution*; (Rutledge and Warden 1999), which remains prevalent in contemporary research (Barnes et al. 2024; Beniermann et al. 2022; Gefaell et al. 2020). Comprising 20 items covering diverse aspects of evolution, from evidence of evolutionary change to

Table 1 Sample description by age, gender, education, and regional comparisons (N, mean, SD, Min/Max)

Region	N	Age			Gender (%)		Education (%)				
		Mean	SD	Min/Max	Male	Female	BGE	Bachelor	Technol.	Degree	Master
Sierra	374	23.1	2.5	20/47	70.1	29.9	0.0	98.7	0.5	0.8	0
Amazonia	691	39.5	7.19	25/64	62.4	37.6	2.8	35.7	60.2	1.3	0
Galápagos	201	42.3	10.34	23/63	69.2	30.8	6.2	6.2	5.1	50.3	32.3
Amazonia vs. Galápagos		ns			ns		< 0.001				
Among Regions		< 0.001			< 0.023		< 0.001				

The probability of the Kruskal-Wallis test for Age and the G-tests for Gender and Education are presented in two comparisons: Amazonia vs. Galápagos, and Among Regions (including the three regions)

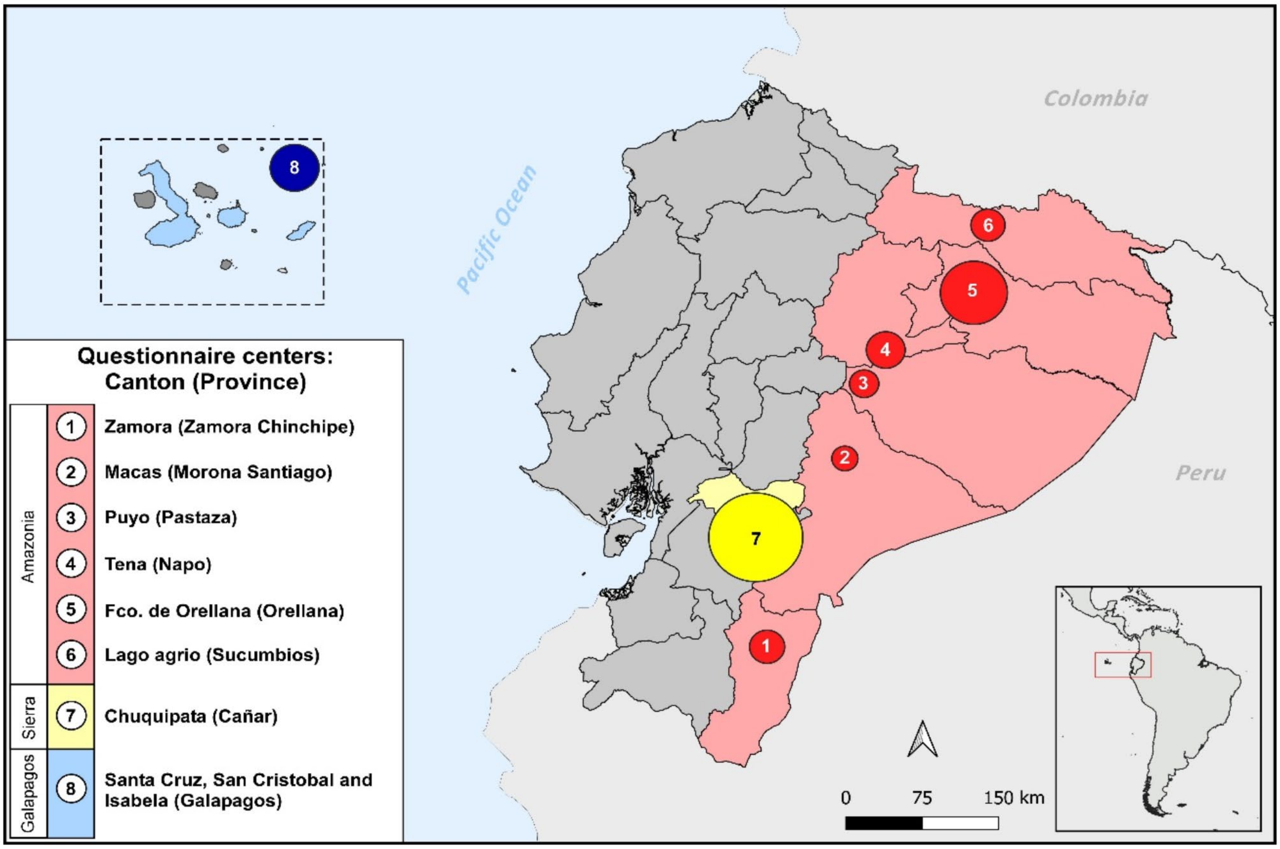

Fig. 1 Location map of questionnaire centers. Map of Ecuador and its different regions (colors) in the context of South America (see inset in the right lower corner), as well as the locations of the centers in which the questionnaires were implemented (circular colored area proportional to the sample size)

human evolution, MATE yields scores ranging from 20 (indicating low acceptance) to 100 (indicating high acceptance). While initially evaluated for content validity (Rutledge and Warden 1999), a recent study has suggested a bi-dimensional structure with two parts: *Facts* and *Credibility* (Rominie et al. 2017). Other recent studies, however, have reported internal consistency and very similar results irrespective of whether the test was structured along two constructs or not (Beniermann et al. 2022; Gefaell et al. 2020). Generally, MATE demonstrates excellent consistency and test-retest reliability (Rutledge and Sadler 2007). A newer version, MATE 2.0, has been preferentially recommended (Barnes et al. 2022) unless comparing with previous estimates is the goal (Barnes et al. 2024). In our study, we opted for the MATE questionnaire due to its availability in Spanish (see Gefaell et al. 2020) and to maintain comparability with prior research in the Latin American region.

Several instruments have been proposed to assess knowledge of evolutionary theory (Beniermann et al. 2022). In the present study, we used the KEE instrument, comprising 10 items that address various aspects of evolutionary theory (Moore et al. 2009). The KEE yields scores ranging from 0 to 10, with 2 representing the expected value under a random response scenario. While not the optimal choice for inferring evolutionary knowledge (Beniermann et al. 2022), the KEE offers a straightforward approach that can be efficiently combined with MATE in interview settings (Gefaell et al. 2020; Zappala et al. 2023). Actually, the combination of KEE and MATE has been frequently employed in many studies (Gefaell et al. 2020; Moore et al. 2009; Rice et al. 2015; Rissler et al. 2014).

To assess intrinsic religiosity, we used the DUREL instrument (Koenig et al. 1997; Koenig and Büssing 2010), comprising three dimensions and five items, each rated on a Likert scale from 1 to 5. The DUREL test evaluates organizational religious activity (ORA; one item), non-organizational religious activity (NORA; one item), and subjective religiosity (IR; three items), with scores ranging from 1 (indicating low religiosity) to 5 (indicating high religiosity). This instrument has been widely employed in over 100 studies across various contexts (Koenig and Büssing 2010).

Statistical methods

The potential multidimensionality, indicating low reliability, of the core variables in this study was assessed using

Cronbach's alpha coefficient (Mead et al. 2019; Romine et al. 2017; Rutledge and Warden 1999), with higher values (closer to 1) indicating greater reliability. We anticipated a favourable performance of the MATE and DUREL instruments, and a poorer performance of KEE, based on prior research findings (Beniermann et al. 2022; Gefaell et al. 2020;).

Associations among categorical demographic variables (e.g., Sex, Studies, Ethnicity, or Region) were analyzed using the maximum likelihood association G-test due to its statistical advantages over classical chi-square tests (Sokal and Rohlf 1995). For the examination of quantitative/ordinal variables (e.g., *Age*, MATE, KEE, DUREL) across different levels of a factor, non-parametric Kruskal-Wallis tests were employed, as this is generally more robust to violations of the normality assumption. The primary objective of the study, however, was to explore the factors influencing evolutionary acceptance (i.e., MATE as a dependent variable). To achieve this, we investigated whether variables related to evolutionary knowledge (KEE), *Education* (assuming a higher familiarity with the nature of science at higher levels of this variable; although see Park and Woodruff 2014), religiosity (DUREL), and sociodemographic variables (*Age*, as there might presumably be substantial sociological differences between generations) could explain variations in evolutionary acceptance through multiple linear regression analysis. Unfortunately, due to the nature of our sample, in which pre-service teachers were only studied in Sierra and in-service teachers only in Amazonia and Galápagos, the teacher-student typology (pre-service vs. in-service) and the region variable are confounded, thus limiting our capacity to disentangle the effects of both variables. However, meaningful comparisons are still possible between the three regions or among the two of these showing the same teacher-student typology (Amazonia and Galápagos).

More specifically, we performed a sequential regression analysis. We initially conducted separate regression analyses of knowledge factors on MATE for each region and the entire dataset combined (all regions pooled), obtaining the corresponding unstandardized residuals (variation in the predicted variable not explained by the regression model). Subsequently, we utilized religiosity (i.e., DUREL) as a predictor of the residuals. This sequential regression approach is commonly used in evolutionary ecology studies to examine the influence of one variable on another after correcting for the contribution of other different variables (Jacob et al. 1996). This method is adequate when the independent variable is not categorical and the objective is fitting regression models (Freckleton 2002). To corroborate the robustness of the sequential regression approach, we conducted yet another parallel regression analysis in which we compared the performance of models including and excluding, respectively a potential key factor (i.e., religiosity). To assess the existence of differences in the slopes of regressions between different regions, we compared nested models whose main difference was the inclusion/exclusion of an interaction between the predictor of interest (religiosity) and a region variable (Poldrack 2023). Prior to any statistical analyses we checked that all participants followed the protocols to participate and that answered to all questions from MATE. All statistical analyses were performed using SPSS/PC software version 24 (IBM Corp 2017).

Results

Cronbach's alpha (C_α) for MATE ranged between 0.72 and 0.87 (Hotelling T-squared test with $P<0.001$ in all cases) on each region separately, while for the pooled data set it was 0.80. Similar or even lower values of C_α were observed when the items from MATE were separated into the *Facts* and *Credibility* dimensions, so there was no support for dividing the MATE test into these two. From now on, we consider MATE as a one-dimensional instrument in our data set. DUREL also yielded a high C_α, with a range between 0.70 and 0.82 ($P<0.001$) across regions (0.79 for the whole set of data pooled). Conversely, KEE showed a much lower C_α value (range 0.32–0.48; $P<0.001$), suggesting certain multidimensionality along its 10 items.

The demographic variables were used to characterize the participants in the three studied regions (Sierra, Amazonia, and Galápagos). The percentage of members of each ethnicity differed significantly between regions (G-test = 334.7; df = 10; $P<0.0001$), with Amazonia showing a majority of self-reported Indigenous (42.8%) and Mestizo (42.8%) subjects and Sierra and Galápagos being mainly composed of Mestizo subjects (96% and 89.6%, respectively). As for their *Province of Birth*, the participants in each region typically come from different provinces (G test = 1779.7; df = 46; $P<0.0001$): preferentially from Napo (24.3%) and Orellana (12.8%) in Amazonia; from Cuenca (64.2%) and Azogues (25.9%) in Sierra; and from Galápagos (28.4%), Guayaquil (18.9%) and Ambato (12.4%) in Galápagos. The results for *Age*, *Gender*, and *Education* are presented in Table 1. As expected based on the characteristics of each sample, mean *Age* differed between Sierra (pre-service teacher students) and the other two regions (in-service teachers), but not between Galápagos and Amazonia (the in-service regions), as revealed by a Kruskal-Wallis test (Table 1). Frequencies of the *Gender* variable were biased towards the male class in all regions, but again only differed between Sierra and the other two (Table 1). Lastly, *Education* differed significantly between all regions (Table 1): Bachelor was the commonest attained qualification (98.7%) in Sierra;

Table 2 Mean, standard deviation (SD), and sample size (N) for MATE, KEE, and DUREL

Region	MATE			KEE			DUREL		
	Mean	SD	N	Mean	SD	N	Mean	SD	N
Sierra	70.0	9.44	374	3.6	1.48	374	2.8	0.91	368
Amazonia	65.8	8.65	693	2.9	1.38	693	3.5	0.73	682
Galápagos	68.8	11.97	201	2.8	1.56	201	3.3	0.90	201
Amazonia vs. Galápagos	≤ 0.001			ns			ns		
Among Regions	≤ 0.001			≤ 0.001			≤ 0.001		

The probabilities of the Kruskal-Wallis non-parametric tests comparing either Amazonia vs. Galápagos or the three regions (Among Regions) are also shown

Table 3 Multiple linear regression of MATE scores by KEE, education, age, and regions

Region	Dependent	DF	R^2	ANOVA	Variables	Beta	Dependent	DF	R^2	ANOVA	Variable	Beta
Sierra	MATE	371	10.2	15.0^{***}	KEE	0.329^{***}						
					Education	-0.022^{ns}	Residuals	365	9.2	38.2^{***}	DUREL	-0.305^{***}
					Age	0.002^{ns}						
Amazonia	MATE	686	4.5	10.7^{***}	KEE	0.160^{***}						
					Education	0.127^{**}	Residuals	675	2.2	15.9^{***}	DUREL	-0.152^{***}
					Age	0.009^{ns}						
Galápagos	MATE	194	12.3	8.9^{***}	KEE	0.341^{***}						
					Education	0.082^{ns}	Residuals	194	11.7	25.5^{***}	DUREL	-0.342^{***}
					Age	0.049^{ns}						
All Regions	MATE	1253	9.2	42.2^{***}	KEE	0.265^{***}	Residual	1236	6.5	86.2^{***}	DUREL	-0.25^{***}
					Education	0.111^{***}						
					Age	-0.106^{***}						

A regression model was fitted for each region separately, and for all of them pooled ("All Regions"). DF is the degrees of freedom used in the analyses, R^2 is the percentage of dependent variable explained by the regression model, and ANOVA is the F tests of the regression models with their corresponding significance values denoted by asterisks ($^{***}P<0.001$, $^{**}P<0.01$, $^{*}P<0.05$). Beta is the standardized regression coefficient; the associated probabilities (see asterisks) were calculated by a t-test. The residuals of the previous model were used as a dependent variable in a second regression analysis (see right columns) where the independent variable was religiosity (DUREL)

Bachelor (35.7%) and Technology (60.2%) in Amazonia; and Degree (50.3%) and Master (32.3%) in Galápagos.

The MATE, KEE, and DUREL results in each region are shown in Table 2. MATE differed significantly between regions, with the following ranking: Sierra > Galápagos > Amazonia. This ranking does not match with differences between regions in KEE or *Education* (Tables 1 and 2), but it is the inverse of that for DUREL (Table 2). The level of evolutionary knowledge (Sierra > Rest) and religiosity (Rest > Sierra) shows that Sierra is different than the two remaining regions (Table 2). These results suggest a complex relationship between academic achievement (*Education*), evolutionary knowledge (KEE), and religiosity (DUREL) as potential predictors of MATE across regions.

When these variables were used in multiple regressions, individual variability in evolutionary acceptance (MATE) was partially explained by the different levels of evolutionary knowledge (KEE), academic attainment (*Education*), and demographic variables (*Age*) in each region separately and the whole dataset pooled (Table 3). The regression was significant in all cases and the percentage of variation explained ranged between 4.5 and 12.3% (Galápagos > Sierra > Amazonia). The residuals of these models were subsequently regressed using religiosity (DUREL) as a predictor (Table 3). The impact of religiosity was always statistically significant and negative, although it explained a different percentage of variation in the residuals in Galápagos and Amazonia (11.7% and 2.3%, respectively), which suggest that religiosity act as an independent factor.

Lastly, the slopes of the MATE residuals' regressions of Amazonia and Galápagos were formally compared to study the possible existence of differences in the (negative) effect of religiosity on evolutionary acceptance between both regions. This was done by running a regression model on these two samples pooled, using the MATE residuals as the dependent variable and an interaction between DUREL and region (Amazonia vs. Galápagos) as the independent variable. This test allows determining whether the slope of the regression assessing the effect of DUREL on MATE is different in each region (Poldrack 2023). The model yielded a significant estimate for the interaction term ($P<0.001$), which can be interpreted as the regression slopes of both regions being different (higher in the Galápagos than in Amazonia).

Discussion

Various studies have highlighted that acceptance of evolutionary theory encounters greater resistance than other equally established scientific theories within biology or other disciplines (Coyne 2009; Miller et al. 2006;

Rutledge and Sadler 2011). This uniqueness has been ascribed to specific challenges inherent to evolutionary theory (Coyne 2009; Ginnobili et al. 2022; Miller et al. 2006; Kelemen 2012; but see Barnes et al. 2020; Fiedler et al. 2018; Lombrozo et al. 2008; Mead et al. 2018). Most academics would agree that the reasons for individual variability in the acceptance of evolutionary theory are predominantly multifactorial (Archila et al. 2023; Heddy and Nadelson 2012) and that the relative importance of the different factors may partially depend on the studied group, and so on their sociocultural characteristics (see for example Oliveira et al. 2022; Zhu et al. 2020).

In the present study, we utilized measures of evolutionary knowledge (KEE), religiosity (DUREL), academic achievement, and demography to gain insights into the acceptance of evolutionary theory in a regionally heterogeneous sample of pre-service teacher students and in-service teachers of Ecuador. Our investigation revealed that both groups—despite coming from different geographical regions—exhibit similar moderate acceptance of evolutionary theory (ranging from 65.8 to 70 on the MATE scale) and rather similar very low levels (following Table 2 from Kuschmierz et al. 2020) of evolutionary knowledge (ranging from 2.8 to 3.6; notice that 2 would be the score attained under a random response scenario). Acceptance levels agree with similar studies conducted in Latin America (Archila et al. 2023; Oliveira et al. 2022; Salazar-Enriquez et al. 2023; Zappala et al. 2023) and other developing nations (Miller et al. 2006; Rissler et al. 2014). Pre-service teacher students displayed slightly higher acceptance rates than in-service teachers, possibly influenced by generational differences, although their different geographic origin limits the inferences we can made on the effect of these factors.

Intriguingly, we observed significant differences in acceptance levels between in-service teachers from the two regions in which this group was studied (Amazonia and Galápagos), despite comparable religiosity levels. The observed disparity in evolutionary acceptance between these regions could be attributed to educational differences (supposedly correlated with scientific knowledge), which significantly vary between subgroups, rather than to evolutionary knowledge or religiosity, which did not show significant differences. Nevertheless, this interpretation is based solely on the comparison between the two groups and should be taken cautiously. Conversely, upon examining individual variability in evolutionary acceptance through linear regression models, we found that this parameter is primarily related to variations in evolutionary knowledge (positive regression coefficient) and religiosity (negative regression coefficient). Even though our model didn't account for most individual variation in evolutionary acceptance (due to unknown factors; revealed by generally low R^2 values), the negative influence of religiosity on evolutionary acceptance differs between the studied regions, warranting further exploration.

In many studies, one of the factors typically negatively biasing evolutionary acceptance is religiosity (Metzger et al. 2018; Moore et al. 2009; Rissler et al. 2014; Rice et al. 2015; reviewed in Heddy and Nadelman, 2012; Kuschmierz et al. 2020; Miller et al. 2006). This might be due to many people seeing evolutionary theory as an atheist alternative to their religious beliefs (Barnes et al. 2020). In our case, we found that the negative effect of religiosity on evolutionary acceptance appears consistent across all studied subpopulations (pre-service teacher students from Sierra and in-service teachers from Amazonia and Galápagos), although their contribution to the regression model ranged from 2.2% (Amazonia) to nearly 11.7% (Galápagos) of the explained variance in MATE when accounting for the rest of factors. Interestingly, we found differences in the predicted regression values between the two studied regions with a similar focal group (in-service teachers; Amazonia and Galápagos), pointing to a greater negative effect of religiosity on Galápagos than on Amazonia. A potential explanation for this finding could be the relatively higher preponderance of evangelist religious groups in Galápagos, which have traditionally displayed an active position against Darwinism (Bassett 2009; Henderson 2021; Weston 2003). This explanation is in line with the hypothesis that religiosity per se is not a problem for acceptance of evolution, but rather certain religions are (Heddy and Nadelson 2012). Future studies should explicitly assess this hypothesis.

Another difference between Amazonia and Galápagos that could be explanatorily relevant is tourism, which could potentially favor a reaction against evolution if this idea is associated with out-group tourists and visitors. The Galápagos Islands, UNESCO's first World Heritage Site, host over 180,000 tourists annually, nearly 6 times the permanent population of the islands (Mazur 2018). Tourism is the main source of income for the islands (Espin et al. 2019). The Amazonia region, on the other hand, due to its climate, vast territorial expanses, often difficult to access, and complex social context, makes this destination not suitable for all audiences. Due to Darwin's voyage of the Beagle (Darwin 2003) and the importance of these islands for his eventual realization of the fact of evolution (Bowler 2009), the idea of evolution is everywhere in the Galápagos. However, the main tourist attraction of the islands is their endemic and unusual fauna, rather than evolution itself (Mazur et al. 2018). In this context, and despite the strong influence of evolution on the islands, Galápagos can still be a very effective platform to preach other beliefs about the origin of species worldwide. An example is the recent inauguration in 2020 by the Seventh-day Adventist Church, a Protestant

Christian denomination, of the Museum of Nature "Origen", a creationist museum right on Charles Darwin Avenue, the nerve center of the most populated island of the archipelago, Santa Cruz.

Although Catholicism is the predominant religion in Ecuador (including the Galápagos islands), it is known that there is a rising trend of Protestant religions in the region, which, besides being resistant to the acceptance of the theory of evolution (Pew Research Center 2014), preach their beliefs through strategic anti-evolutionist movements (Borgerding and Deniz 2018; Chicaiza and Varea 2014). That is, although the proportion of adherents to religions that reject the theory of evolution is smaller on the islands compared to religions more inclined to accept it, the anti-evolutionist message can resonate with the population if the anti-evolutionist religion has a large community that supports and actively preaches its beliefs. On the other hand, Bastian (2006) points out that in Latin America, religion is constantly changing, even coining the concept of "religious mutation" where the author proposes that charisma plays a leading role in social change. In this sense, the Galápagos Islands lend themselves as that charismatic place to preach to the world the different beliefs about the origin of species. For the reasons above, we cannot rule out that the negative association between religiosity and acceptance might be due to a mediating unexplored variable, like the specific religious denomination involved, outreach strategies, or charisma. These possibilities demand further exploration in the future.

As for evolutionary knowledge, the results obtained in the present study should be interpreted with caution due to the technical limitations of the KEE instrument (Beniermann et al. 2022). That said, the data presented here suggests that relatively moderate levels of evolutionary acceptance can be attained even with very low levels of evolutionary knowledge, a phenomenon commonly observed in several other studies (Gefaell et al. 2020; Kuschmierz et al. 2021). The low level of evolutionary knowledge could be attributed to various factors; one of these might be high religiosity as well. Students who undergo courses in evolutionary biology might be hesitant to embrace the theory of evolution, particularly when they perceive a conflict with their religious beliefs (Chinsamy and Plagányi 2008). Another explanation may be the curriculum treatment of evolution. Although it is really valuable that theory is included in Elementary Education, the lack of recommended learning progression (Corcoran et al. 2009; Duschl et al. 2011; Furtak and Heredia 2014; NGSS Lead States 2013) in its treatment can be a learning obstacle. This could make it difficult for students to create the complex network of core ideas that make up the theory and could have consequences in the following educational stages. Another potential explanation could be differences in individual prosperity between the studied areas of Ecuador, as this has been suggested as a key causal factor in many countries (Heddy and Nadelson 2012). Additionally, we observed that individual variability in acceptance was similarly influenced by evolutionary knowledge and religiosity, with both factors contributing significantly albeit with opposing signs and independent effects. This leads us to highlight teacher training programs that different entities such as Galápagos Conservancy and Scalesia Foundation, in coordination with the Ministry of Education, carry out in the Galápagos Islands (Román et al. 2015, 2020), improving the scientific education in general and evolution knowledge in particular. Furthermore, developing an intentional instruction focused on the compatibility of belief and evolution can lead to increased evolution acceptance among religious students (Lindsay et al. 2019).

In sum, while we have identified factors explaining 7–20% variation in evolutionary acceptance (Supplementary Materials, Table S1), such as religiosity or evolutionary knowledge, we have not pinpointed the primary drivers behind the non-explained variance proportion. Thereby, we suggest that future studies should include other sociocultural variables in the demographic section of the questionnaire, as well as other macro- and microeconomic indicators of the regions studied, given their potential explanatory role (Zhu et al. 2020; Oliveira et al. 2022). For instance, individual economic prosperity could account for up to 42% of the variance in evolutionary acceptance (Heddy and Nadelson 2012). Furthermore, other potential influences, such as the tendency to consume natural commercial videos, engage with natural history and science outreach journals, or exhibit a general cultural interest in nature (as suggested by Zhu et al. (2020), have not been systematically explored. Additionally, the fourth Ecuador region, Costa, must also be included in future studies, which should also avoid any confounding factors between regions and teacher-student typology. In this sense, we are just still starting to understand why a fundamental scientific theory like evolution encounters such resistance in so many social groups.

Conclusions

The acceptance of evolutionary theory in Ecuador, as in many other regions of the world, appears to be a complex phenomenon influenced by multiple sociocultural, educational, and religious factors. The results of this study reveal that, while moderate levels of acceptance of evolution are observed, the lack of in-depth knowledge about the theory of evolution and the negative influence of religiosity are key factors shaping acceptance. The variability in acceptance observed between pre-service teacher students and in-service teachers, as well as the regional differences between Amazonia and the Galápagos Islands, suggest that the educational context and the presence of anti-evolutionary religious movements could constitute determining elements in attitudes toward evolution. However, despite identifying some explanatory factors, much of the variability in the acceptance of evolutionary theory remains unexplained, highlighting the need for further research into additional sociocultural variables and macro- and microeconomic factors that may contribute to a better understanding of this phenomenon. Therefore, it is crucial to strengthen scientific research on the causes of rejection of evolutionary theory, as well as to promote pedagogical approaches that coherently integrate evolutionary knowledge with personal beliefs, ultimately fostering greater acceptance of this fundamental theory.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12052-025-00219-2.

Supplementary Material 1: **Table S1**. Regression model. Contribution of all different variables to the explained variance in MATE.

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Author contributions

Conceptualization: LTM, JMSR, JGef, ERA; Supervision: LTM, JMSR, JGef, ERA; Data collection: LTM, JMSR, AP, BM, LA, IG, HA, AS, DL, ML; Data Analysis: JGef, ERA, AB; Drafting: JG, ERA; Writing: JGef, ERA, LTM, JMSR, AB; Revisión: JG, MB. All authors reviewed the manuscript.

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Data availability

The dataset supporting the conclusions of this article is available in the Zenodo repository, https://doi.org/10.5281/zenodo.14410122.

Declarations

Competing interests

The authors declare no competing interests.

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