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Knowledge and acceptance of the Evolutionary Theory among pre-service primary teachers

Conoscenza e accettazione della teoria evoluzionistica tra i futuri insegnanti di scuola primaria

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Abstract
The theory of evolution by natural selection, proposed by Charles Darwin in 1859, is a complex and multifaceted concept. Teachers play a central role in delivering scientifically accurate concepts on evolutionary theory, starting from primary school. Using the Evolution Education Questionnaire on Acceptance and Knowledge (EEQ), the level of knowledge and acceptance of evolutionary theory was investigated among future teachers (students enrolled in the Primary Teacher Education degree at the University of Bologna). The study identified potential variables that might influence higher or lower levels of acceptance and understanding, including age, religious faith, gender, and previous high school education. It also examined the effect that scientifically accurate teaching of evolutionary theory could have on students enrolled on this degree. The results indicated no significant correlations between the identified variables and levels of knowledge and acceptance. This suggests that factors influencing greater or lesser comprehension and acceptance of evolution by natural selection may lie in other contextual variables. The study found that scientifically accurate teaching of evolution positively influenced scientifically accurate responses, leading to an improvement in the understanding of evolutionary mechanisms.

Keywords: evolutionary theory; pre-service teacher; Primary Teacher Education; University

Riassunto
La teoria dell'evoluzione per selezione naturale, proposta da Charles Darwin nel 1859, è un concetto complesso e articolato. Gli insegnanti rivestono un ruolo chiave nel trasmettere concetti scientificamente accurati sulla teoria dell'evoluzione, a partire dalla scuola primaria. Usando il Evolution Education Questionnaire on Acceptance and Knowledge (EEQ), sono stati indagati i livelli di conoscenza e accettazione della teoria dell'evoluzione tra i futuri insegnanti (studenti che frequentano il Corso di Laurea in Scienze della Formazione Primaria presso l'Università di Bologna). Lo studio ha evidenziato possibili variabili che potrebbero influenzare maggiori o minori livelli di accettazione e conoscenza della teoria dell'evoluzione, tra di essi ci sono età anagrafica, fede religiosa, sesso e studi superiori. Sono stati anche indagati gli effetti che un insegnamento scientificamente accurato della teoria evolutiva potrebbe avere sugli studenti di questo corso.I risultati mostrano come non siano individuabili correlazioni significative tra le variabili precedentemente citate e i livelli di conoscenza e accettazione. Questo suggerisce che ciò che condiziona un maggiore o minore livello di conoscenza e accettazione della teoria dell'evoluzione per selezione naturale sia da ricercare in altre variabili riferite al contesto. Lo studio ha anche riportato come un insegnamento scientificamente accurato dell'evoluzione influenzi in modo positivo le risposte scientificamente accurate, portando anche ad un miglioramento rispetto alla comprensione dei meccanismi evolutivi.

Parole chiave: teoria dell'evoluzione; insegnanti pre- service; Scienze della Formazione Primaria; Università.

Credit author statement
These authors equally contributed to this work.

1. Theoretical background

1.1 Kwoldge and acceptance of the Evolutionary Theory

Studies about the knowledge and acceptance of the evolutionary theory are not very common in Italy, but if we widen the scope to abroad studies, the number increases. The United States is a primary contributor to these studies and various scholars attribute/assign this extensive presence to the widespread opposition to the theory of evolution and the deep-rooted tradition of creationism (Scott, 2008; Brenan, 2019). On the other hand, studies conducted in Europe show that, overall, the acceptance rate of evolutionary theory is higher (Miller et al., 2006; Kuschmierz et al., 2021). Among the research conducted in Europe, only a few international comparative studies have included the European continent. This lack of comparative studies led researchers to adopt a more cautious approach. In the decade between 2010 and 2020, only four European countries – Germany, Greece, Turkey and United Kingdom – published three or more articles on the topic of evolution's acceptance (Kuschmierz et al., 2020b).

These findings reveal a significant gap in European research regarding comparative studies; however, the situation changed in 2021 with the introduction of a comprehensive study to measure levels of acceptance and knowledge of the theory of evolution (Kuschmierz et al., 2021). This study sampled 11,723 first-year university students from 26 European countries using the standardised test called "Evolution Education Questionnaire on Acceptance and Knowledge" (EEQ); this instrument allowed comparisons despite differences in language, education systems, and research communities across European countries (Kuschmierz et al., 2021) and targeted first-year students who had recently graduated from high school to identify misconceptions and assess the effectiveness of national education systems. The questionnaire was specifically designed to assess acceptance, knowledge of the evolutionary theory, and religious faith.

The results of this large-scale study showed that, generally, university students accept the theory of evolution, but lack fundamental knowledge of it. It was also noted that students with lower levels of acceptance of evolutionary theory scored lower in knowledge and higher in religious faith; religious faith had a much greater influence on acceptance than knowledge. Additionally, the country of origin had a minimal impact on the acceptance of evolution (Kuschmierz et al., 2021). Another interesting study is one conducted in Indonesia in 2018, which sought to investigate the knowledge and acceptance of the theory of evolution among future biology teachers (Rachmatullah et al., 2018). Indonesia is a country where religion plays a central role in people's lives and is integrated into school curricula to such an extent that teachers are encouraged to invite students to consider connections between evolutionary theory and religious or spiritual perspectives. Using the ACORNS (Assessment of Contextual Reasoning about Natural Selection; Nehm et al., 2012) tool, future biology teachers were asked to answer to four open-ended questions, providing explanations for evolutionary phenomena (Nehm et al., 2012; Opfer et al., 2012). The results from Indonesia were compared with an American sample, revealing that the latter referred more frequently to natural selection; the Indonesian sample demonstrated less use of scientific reasoning, favoring naïve models (particularly showing extensive use of Lamarckian theories). The study revealed that knowledge of evolutionary mechanisms was relatively low compared to the American sample, while the levels of acceptance of the evolutionary theory and its scientific validity were relatively good (Hoag, 2009).

1.2. Correlation between knowledge of evolution, acceptance, and religious faith

For decades, the scientific community has debated the possible correlation between knowledge of the theory of evolution and its acceptance. However, no unanimous or consistent conclusion has been reached to this day. While some studies highlight a positive correlation between these factors (Nadelson et al., 2009; Athanasiou & Papadopoulou, 2011; Akyol et al., 2012; Großschedl et al., 2014), other refute any connection between knowledge and acceptance of the evolutionary theory (Akyol et al., 2010; Athanasiou et al., 2016).

In students aged 6 to 18, the correlation between acceptance and knowledge of the evolutionary theory is often weak or absent (Kuschmierz et al., 2020). On the contrary, studies investigating this correlation

among pre-service or in-service teachers show that it is positive, albeit moderate or weak (Großschedl et al., 2014; Deniz & Sahin, 2016).

Previous studies in Europe have shown that religious faith and acceptance of the evolutionary theory are strongly correlated across educational levels: lower acceptance levels are associated with higher levels of religious faith (Eder et al., 2011; Clément et al., 2012; Athanasious et al., 2016; Deniz & Sahin, 2016; Betti et al., 2020). Nevertheless, Kuschmierz's research indicates that this phenomenon is limited to certain European countries (Kuschmierz et al., 2020b). Additional studies suggest differences in acceptance across various religious denominations (Smith, 2010; Southcott & Downie, 2012; Athanasiou et al., 2016; Konnemann et al., 2016; Beniermann, 2019).

2. Materials and Methods

The research is an observational-correlational survey in three/six different cohorts/years of the Single-Cycle Master's Degree Course in Primary Teacher Education of the Alma Mater Studiorum University of Bologna (PTE course), which aims to investigate the degree of knowledge of the evolutionary theory, of acceptance of it and the possible relationship with religious faith in future teachers. Within the scope of this research, the level of knowledge of the theory of evolution is set up as a dependent variable, while religious faith, age of birth, biological sex and type of high school studies are treated as independent variables.

Based on these variables, it is hypothesized that:

- there is a correlation between the knowledge of the evolutionary theory, the acceptance of it and the following variables: religious faith, age of birth, biological sex, and year of course;
- students who possess an index with higher values related to religious faith have less knowledge and acceptance of the evolutionary theory than their peers who have lower scores;
- students who have a higher age know and accept the evolutionary theory less than their younger colleagues;
- students who have just taken the Elements of Biology course (third year of the PTE course) or who are in the final year of the degree program know and accept the evolutionary theory more than their first-year colleagues.
- no differences are reported in the level of knowledge and acceptance of the evolutionary theory with respect to biological sex.
- Null Hypothesis (H0): it is assumed that there are no differences in the knowledge and acceptance of the evolutionary theory either by reported scores with respect to religious faith, nor with respect to registry age, nor with respect to course year and higher education, while there is a difference with respect to biological sex.

From these hypotheses, descriptive, correlational, significance tests and linear regression analyses were performed. Exploratory factor analyses were also conducted in order to validate the scales.

The type of research sampling is non-probability and convenience sampling: subjects were selected on the basis of convenience criteria to which to submit the questionnaire: in this case, the explicit willingness of participants to answer the questionnaire in the three selected annualities. The three annualities (first, third and fifth) were selected with the following criteria:

- the first PTE annuality to take a snapshot of the level of knowledge and acceptance of the evolutionary theory among the cohort of students who had just entered the university;
- the third annuality to see if the cohort of third-year students change their level of knowledge and acceptance of that theory after they took the Elements of General Biology course that covered and explored the topic in depth. However, it is worth noting that the course was not explicitly targeted on the questionnaire items, which aims to measure the competences in evolutionary rationales rather than specific notions.
- the fifth year to test the same variables in the cohort of students who have come close to the end of their undergraduate journey before officially entering the world of education.

The students of the PTE Course at the University of Bologna who voluntarily responded to the questionnaire numbered 230: 135 in the first annuality, 58 in the third and 37 in the fifth. Most of the students were between the ages of 18 and 22 (n = 161), followed by students between the ages of 23 and 27 (n = 58), and the remainder were older than 28 (n = 11). Participants in this observational-correlational survey completed Evolution Education Questionnaire (EEQ) questionnaires previously validated by other research (Beniermann et al., 2021; Kuschmierz et al., 2021) and designed specifically to assess acceptance and knowledge of evolutionary theory and religious belief. Specifically, the Knowledge About EVOlution (KAEVO) 2.0 test (Kuschmierz et al., 2020a) was used, as well as the Attitudes Towards EVOlution (ATEVO) test, based on 4-level agreement Likert scales, and the PErsonal Religious Faith (PERF) test, based on 5-level agreement Likert scales (Beniermann, 2019). The PERF test was designed to measure the religious faith for all religions in the same way. The KAEVO test is comprised by three sections: KAEVO-A (12 multiple-choice items focused on evolutionary adaptation and natural selection), KAEVO-B (12 true or false items focused on general ideas – and misconceptions – about biological evolution) and KAEVO-C (placement of precise events on the Earth timeline). KAEVO-A aims to identify the preferred explanation of adaptation, including a correct rationale based on natural selection and naïve explanations. Naïve explanations were categorized as: Automatic (adaptations spontaneously occur in organism in response to environmental pressures); Anthropomorphic (like humans, organisms identify flaws and areas of improvement and train to get better adaptations); Teleological, nature-centered (some entity identified as "Nature" actively works to improve organisms); Teleological, organism-centered (the organism decides to adapt to improve its performances in the environment); Lamarckian (the organism strives and adopts some habits and morphological changes that are inherited to the offspring).

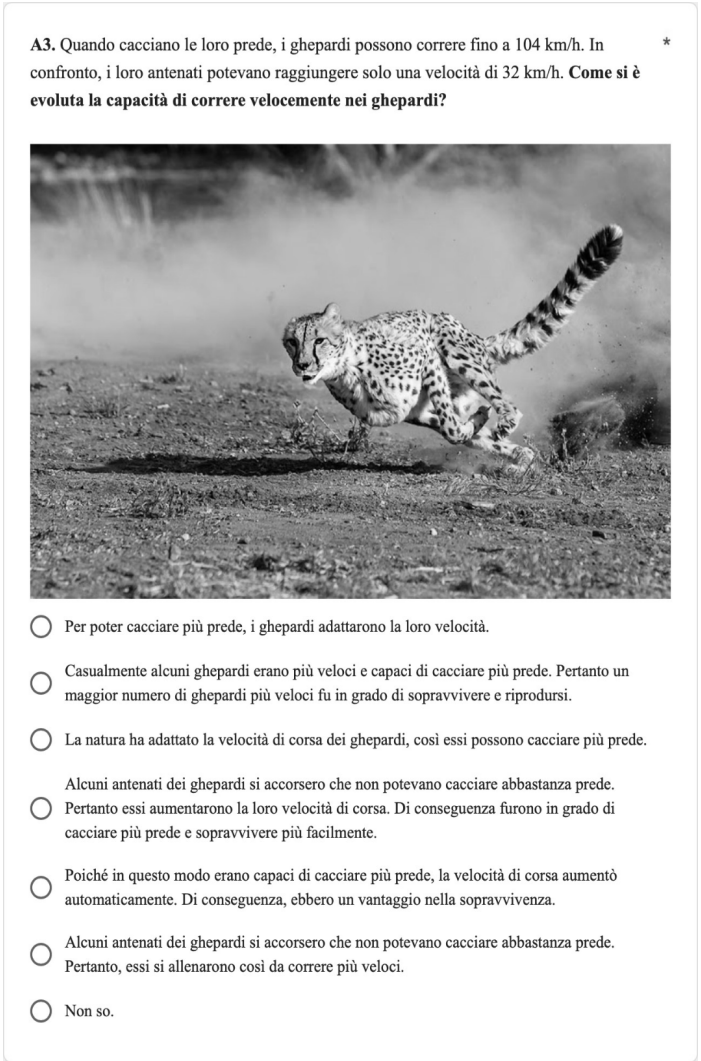

Fig.1: Item A3 from the KAEVO-A test, translated into Italian. For the original item, see Kuschmierz et al. (2020a).

Answers were classified as Teleological (organism-centered), Accurate (the correct rationale, based on natural selection), Teleological (nature-centered), Lamarckian, Automatic, and Anthropomorphic, respectively. The last answer states "I do not know". An example of KAEVO-B item is: "The biological evolution of Mankind is completed".

Categories are available to allow standardized interpretation of the results of all three instruments (Beniermann et al., 2021; Kuschmierz et al., 2020a). The original questionnaire (EEQ) was translated in Italian and repurposed. Exploratory factor analyses, carried out following the translation of all scales, returned a fairly good internal consistency for the 24-item KAEVO test (Cronbach's Alpha, 0.71), including KAEVO-A and KAEVO-B. The ATEVO scale achieved almost the same internal consistency value (0.70), while the PERF scale recorded an excellent Cronbach's Alpha Index value instead (0.96). The administration was done online, through a Google Forms link. Globally, the EEQ test scored an internal consistency value equal to 0.85. The estimated time for completion averaged 30 minutes. In this study, the questionnaires were completed anonymously and the analyses were carried out in aggregate form.

3. Results

Among the explored independent variables, having dealt with evolution in high school does not seem to affect KAEVO score (Kruskal-Wallis $\chi 2$-associated P-value=0.9122), ATEVO score (P=0.1689) or PERF score (P=0.6134). The same holds for the last year during which biology subjects were taught in high school (P-value equals to 0.2570, 0.9875, and 0.6652, respectively).

We found an effect of interest in biological evolution and self-confidence about it on KAEVO scores (Fig. 2): students more interested in evolution show significantly (based on Dunn's post hoc test) higher KAEVO scores, as well as students feeling more confident with this subject. However, neither self-confidence nor interest was associated to ATEVO (P=0.0053**, but no significant Dunn pairwise comparison) or PERF (P=0.8873) scores.

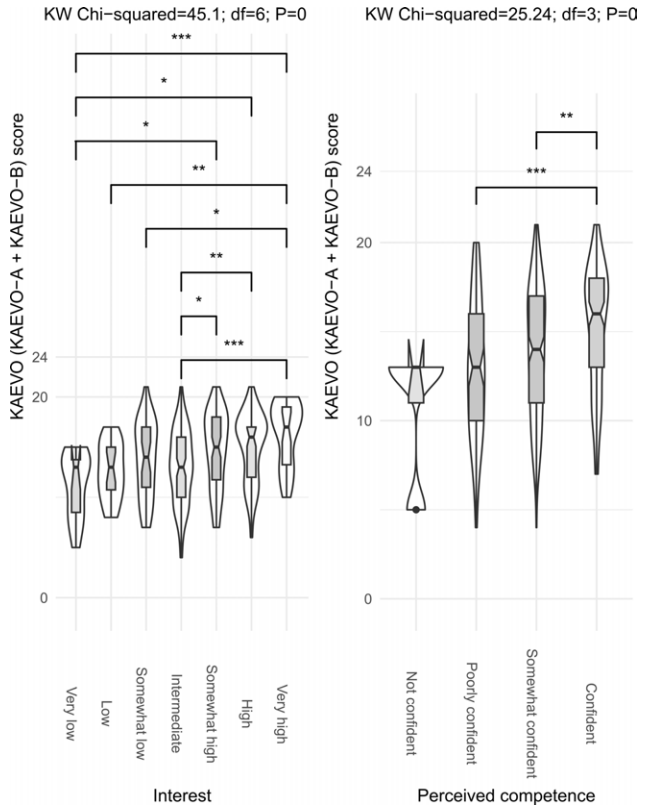

Fig. 2: Effect of interest in evolutionary theory and self-confidence about it on KAEVO score. Violin plots show the data distribution via kernel density estimation; box plots represent the interquartile range, with notches indicating the median. Outliers are shown as black dots. Only KAEVO A and KAEVO B are used. *, P < 0.05; **, P < 0.01; ***, P < 0.001.

Interestingly, we found an effect of biological sex (Fig. 3).

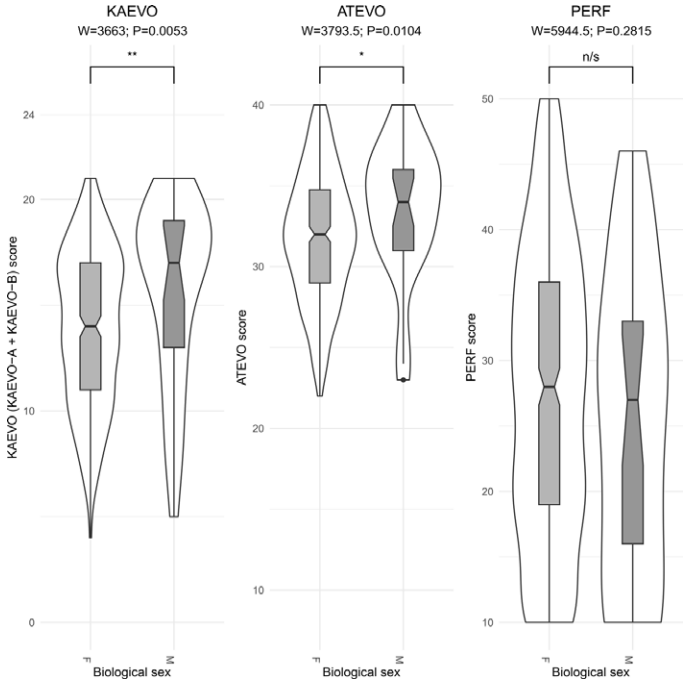

Fig. 3: Effect of biological sex on KAEVO, ATEVO, and PERF scores. Violin plots show the data distribution via kernel density estimation; box plots represent the interquartile range, with notches indicating the median. Only KAEVO A and KAEVO B are used for KAEVO. *, P < 0.05; **, P < 0.01; ***, P < 0.001.

Male students have significantly higher KAEVO and ATEVO scores (Wilcoxon rank-sum test), indicating deeper knowledge and better acceptance of the evolutionary theory; conversely, there was no significant difference in PERF scores.

The largest effect on EEQ results was shown with respect to course year (Fig. 4).

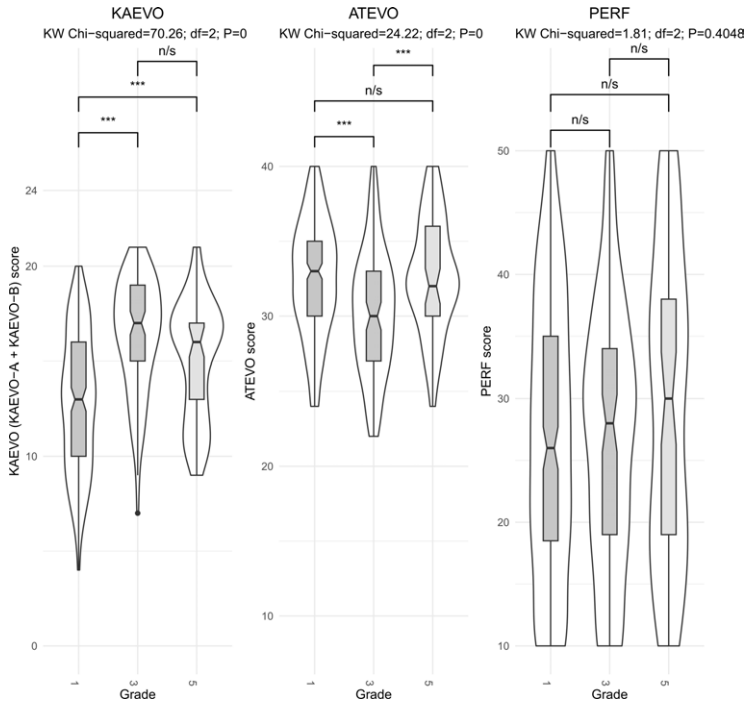

Fig. 4: Effect of course year on KAEVO, ATEVO, and PERF scores. Violin plots show the data distribution via kernel density estimation; box plots represent the interquartile range, with notches indicating the median. Outliers are shown as black dots. Only KAEVO A and KAEVO B are used for KAEVO. *, P < 0.05; **, P < 0.01; ***, P < 0.001.

Students are taught about evolution in the biology course at the third year: indeed, third-year students show significantly higher KAEVO scores with respect to first-year students; moreover, we found no significant difference in KAEVO among third-year and fifth-year students. Interestingly, however, the ATEVO scores of third-year students is significantly lower when compared to first-year and fifth-year students. Finally, enrolling year is not associated to PERF scores. The wrong answers of four questions in the KAEVO A section can be classified under different types of naïve explanations: A1, concerning the carnivorous plant *Dionaea*; A3, concerning cheetas; A5, concerning the pulmonate *Cepaea*; A6, concerning desert plants. Frequencies of correct answers are significantly higher during the third year, yet they significantly decrease during the fifth one (Fig. 5), when automatic explanations regain popularity. Overall, we found a weak positive correlation between KAEVO and ATEVO, but no correlation with PERF (Fig. 6). Interestingly, we found a weak positive correlation between age and KAEVO, hinting for a better knowledge of the evolutionary theory among more mature students.

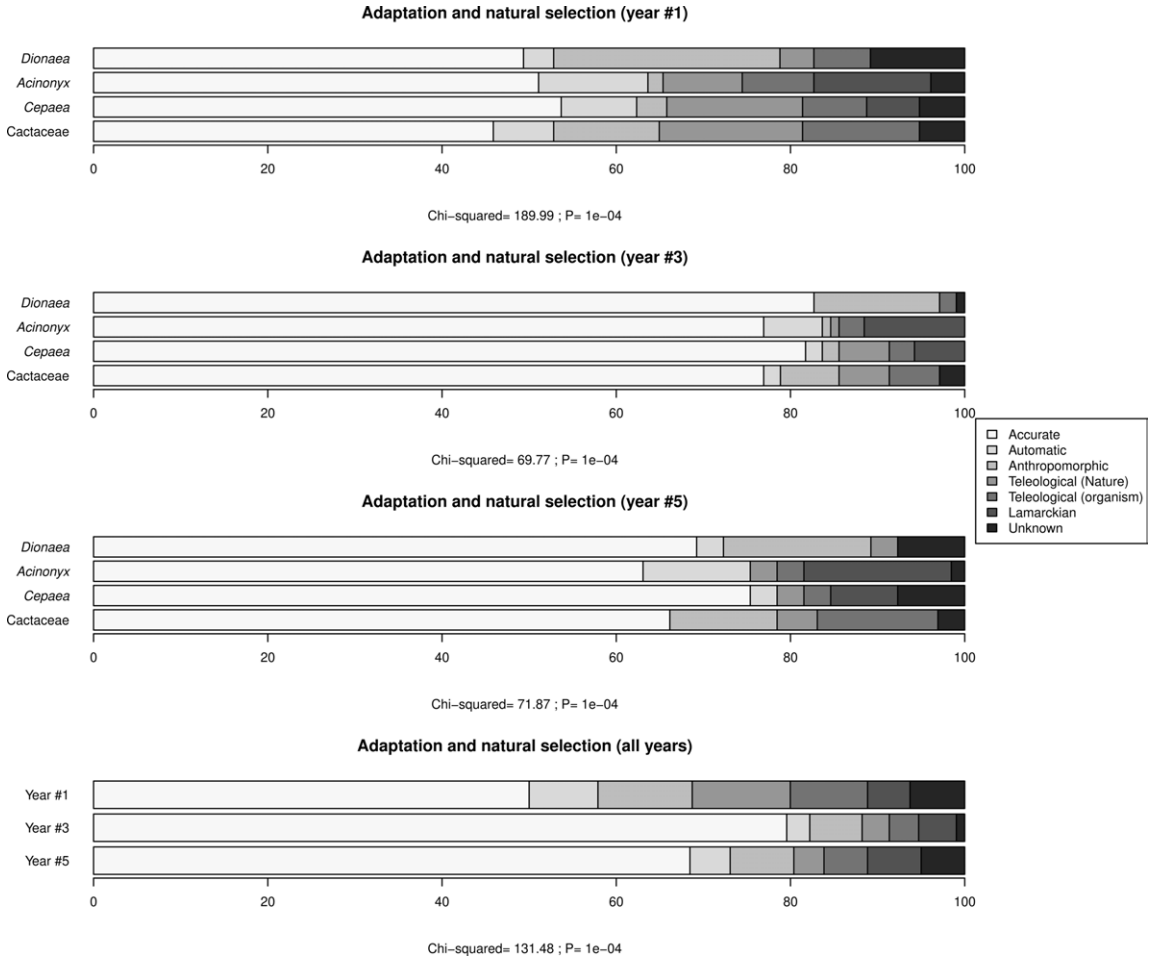

Fig. 5: Fig. 4. Distributions of different types of naïve explanations to items A1, A3, A5, and A6 of KAEVO A.

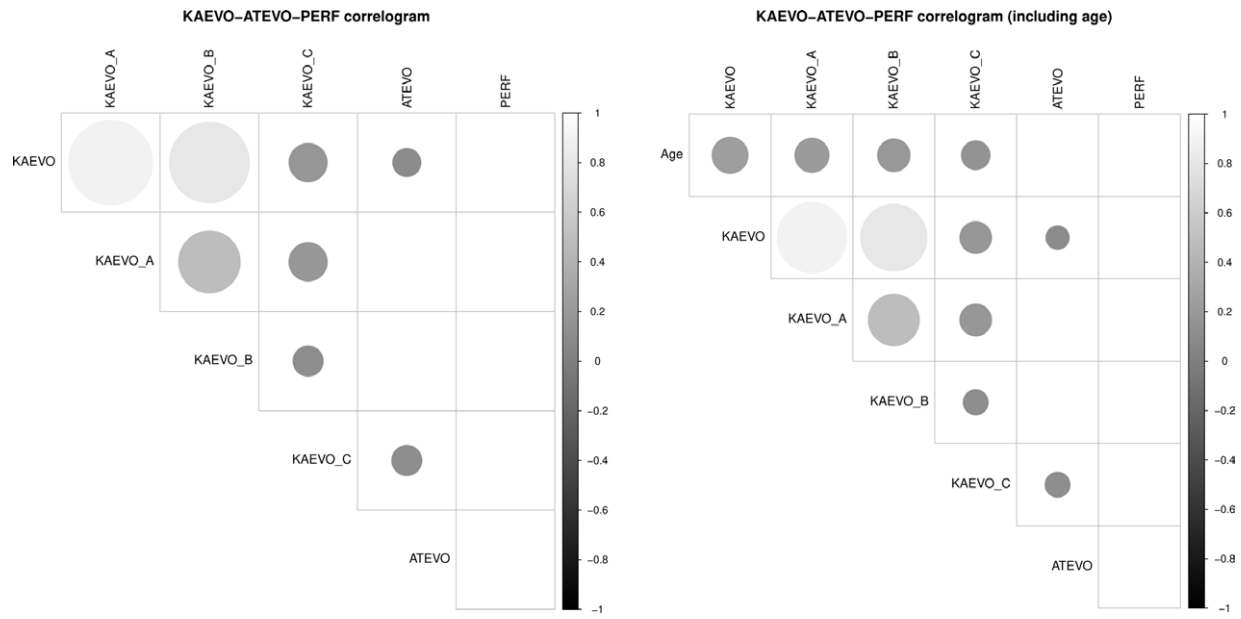

Fig. 6: Correlogram for student age, KAEVO (meaning KAEVO A+KAEVO B), KAEVO A, KAEVO B, KAEVO C, ATEVO, and PERF. The diameter of the dot is proportional to the associated Spearman's ρ; non-significant (i.e., $P > 0.05$) Spearman's ρ are not shown.

4. Discussion

A little effect of interest and perceived competence on actual knowledge on evolutionary theory is somewhat expected. We interpret the effect of biological sex on KAEVO and ATEVO in the wider context of gender biases in STEM subjects, which lead to similar results in different disciplines (e.g., math; physics). It is interesting to notice that the increase in KAEVO scores after exposition to a structured teaching on evolution does not lead to an improvement in acceptance of evolution; instead, a decrease is observed (Fig. 3). We interpret this as an effect of the exposition to the multiple caveats of biological evolution. Instead of a general (and essentially wrong) notion of some law of progress in nature, students are taught the essential core of Darwinism and the importance of historical, unpredictable events: this may lead, as an immediate response, to a lower acceptance of evolution, which increases again after some time of knowledge reorganization. Two years after the course there is not significant decrease in KAEVO, even if naïve explanations regain popularity (Fig. 4). This suggests the relevance of a lifelong education of key scientific subjects, as is the theory of evolution.

It is also worth noting that we found no association between religious faith (PERF results) and knowledge or acceptance of the evolutionary theory. This was not completely expected, since some influence of religious faith on the acceptance of the theory of evolution was shown by the keynote study by Kuschmierz and colleagues (2021). Moreover, previous studies found a clear, negative correlation between religious faith and acceptance of the evolutionary theory in Europe (Eder et al., 2011; Clément et al., 2012; Athanasious et al., 2016; Deniz & Sahin, 2016; Betti et al., 2020). Nevertheless, it was also found that different Europena countries behave in different ways (Kuschmierz et al., 2020b), and the same holds for different religious denominations (Smith, 2010; Southcott & Downie, 2012; Athanasiou et al., 2016; Konnemann et al., 2016; Beniermann, 2019). Addressing this issue for a country where religion plays a central role in people's lives, such as Indonesia, demonstrated that there is a clear correlation between religious faith and the acceptance of the theory of evolution (Rachmatullah et al., 2018), while the same is not true for countries where religion is typically more restricted to the private life (Reiss, 2018). All this considered, it is tempting to conclude that the current combination of religious pervasiveness and scientific literacy in Italy does not lead to a negative correlation between religious faith and acceptance of the evolutionary theory, at least for pre-service pre-primary and primary teachers of the University of Bologna.

5. Conclusions

The importance of an academic teaching of evolution and evolutionary theory has been clearly shown in the present study (Fig. 4). The fact that some types of naïve explanations respawn years after being exposed to an academic course underlines this importance the more. Interestingly, these are Automatic explanations, as if all the caveats of natural selection were lost beneath the general figure of its deterministic quality: given a sufficient amount of time and individuals, adaptation through natural selection is indeed expected to occur (even if it is never possible to predict how). Therefore, we highly recommend to consider the origin of mutations a highly relevant point in teaching biology: mutations do not occur in response to environmental pressures, they simply occur – natural selection will do the rest with mutations that turn out to be advantageous to some extent.

Moreover, a great care in language is recommended: as in the case of these Automatic explanations (see Fig. 1), many misconceptions arise and persist because of linguistical simplifications adopted in order to straightforward teaching and learning. If there was a strong grounding in natural selection, such verbal shortcuts may prove useful, in that they contribute to a smoother speech; however, without a proper evolutionary literacy, such expressions may lead to misconceptions themselves.

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