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From conflict to harmony: changing conceptual ecology of evolution acceptance of muslim students after dialogue in science and religion

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Abstract

Muslim students have a high perceived conflict between religion and evolution. For this reason, constructivist teaching was implemented to emphasise the balance of the nature of science (NOS) on evolution and creationism theory within the conceptual ecology for biological evolution (CEBE) framework. This study explored changes in students' CEBE and how perceived conflict, NOS, and religion contributed to the evolution of acceptance during the course. This research followed a one-group pre-test and post-test design to gather data. Data collection tools used in this study included a questionnaire and a reflective essay. The study group consisted of third-year undergraduate biology students aged 20–22 from Universitas Islam Negeri Maulana Malik Ibrahim Malang in Indonesia. Questionnaire responses were analysed using statistical methods, including paired t-tests, correlation, and hierarchical regression, while reflective essays were analysed using content analysis. The study found that students' acceptance increased after the course and was correlated with their knowledge, religiosity, understanding of NOS, and perceived impact. The understanding of NOS was the primary factor influencing the acceptance of the theory of evolution, while perceived conflict has the least impact. In addition, reflective essays showed that while most students had a naive knowledge of evolutionary reasoning, they could explain the nature of science. The students were able to establish a complex relationship between science and religion using the chimpanzee-human relationship explanation. This study has provided an example of a learning method to minimise students' perceived conflict in the evolution course.

Keywords Theory of evolution acceptance, Perceived conflict, Religion, Evolution NOS, Conceptual ecology for biological evolution

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Introduction

The information from the literature indicates that there is no single answer to the problem of evolution acceptance among university students. Previous studies have only focused on one factor (Wilson 2005) or several factors (Athanasiou et al. 2012; Athanasiou and Papadopoulou 2012). In Indonesia, most studies only explore biology students' knowledge and perceptions of the theory of evolution without investigating the factors that promote or hinder the acceptance of evolution (Aini et al. 2020;

Rachmatullah et al. 2018). Previous research indicates a weak correlation between knowledge of evolution and acceptance of it (Deniz et al. 2008; Pintrich et al. 1993). In other words, most studies have investigated knowledge and beliefs about evolution, but they lacked several essential factors that influence acceptance of evolution (Athanasiou et al. 2016).

In addition to knowledge-based factors, it is crucial to consider several affective factors as determinants of students' acceptance of the theory of evolution (Pobiner 2016). The revisionist approach acknowledges the limitations of the conceptual change model and recognises the significant role of affect in cognition (Gregoire 2003), which accommodates intuition, emotion, motive, and social factors. Affective factors act as a conceptual ecology (CE) that changes when a conceptual change occurs. In other words, CE refers to the process of controlling and modifying the acceptance of change and evolution among university students (Strike and Posner 1992). The acceptance of theory of evolution among university students is influenced by their affective factors and the complex relationship between them (Deniz et al. 2008).

The role of affective factors can provide more compelling and coherent explanations of how students' acceptance of evolution can be influenced (Athanasiou et al. 2016). Nowadays, it is evident that several factors are considered constituents of conceptual ecology for biological evolution (CEBE), such as knowledge of evolutionary theory, understanding of the Nature of Science (NOS), and dispositional thinking (Demastes et al. 1995a, b; Deniz et al. 2008). The composite of many other factors on CEBE has received attention from researchers as a factor that can hinder or enhance conceptual change (Demastes et al. 1995a, b; Sinatra et al. 2003). Park (2007) also confirmed that some factors on CEBE significantly limited or enhanced learning effectiveness.

Accordingly, it is essential to emphasise that this study on the acceptance of the theory of evolution was conducted as an integral part of the CEBE (Posner et al. 1982; Strike and Posner 1992). This study was conducted to narrow the gap by measuring changes holistically——not only from the knowledge aspect——by considering affective factors that can potentially influence the acceptance of evolution after a course. The CEBE in this study included acceptance of evolution, level of knowledge, perception of evolution-related NOS, religiosity, epistemological beliefs, and thinking dispositions, which are all the factors that impacted university students' conception of evolution (Demastes et al. 1995a, b). As expected, this study explains why some university students demonstrated high acceptance levels while others displayed low levels (Deniz et al. 2008).

The CEBE component may differ across societies due to contextual factors. This particular condition has been observed in certain societal circumstances (Athanasiou et al. 2016). Hence, it is essential to examine CEBE within the framework of Indonesian Muslim biology students. Indonesia is a religious country where the majority of the society adheres to one or another religion (Paker and Özcan 2017), has vital local wisdom and culture (Anggraini and Kusniarti 2015), has an excellent opportunity to contribute moderate evolutionary education insights by seeking harmonisation between evolution, culture and religion (Rachmatullah et al. 2018). As the country with the world's largest Muslim population, Indonesia had almost 230 million Muslims in 2020 (Global Religious Futures 2020). Indonesia is interested in creating an education that harmonises evolution and religion for Muslim biology teachers. As described by BouJaoude et al. (2011) and Downie and Barron (2000), it has been observed that a significant proportion of individuals who do not accept the theory of evolution are Muslims.

Previous studies more than two decades ago (Dagher and BouJaoude 1997) to the latest (Barnes et al. 2021) reported that Muslim students had a high perceived conflict with their belief in God and evolution. University students expressed how their religious teachings conflicted with their acceptance of evolution (Barnes et al. 2020a, b; Firdaus et al. 2021). Other reports, such as Barnes et al. (2020a, b), mentioned that almost half of biology students——including religious ones——thought they had to become atheists to accept evolution. Students have highlighted the differences between religious beliefs and the theory of evolution regarding the universe's creation (Barnes et al. 2017; Barnes et al. 2020a, b). Hence, the conflict between religious beliefs and evolution is among the strongest predictors of acceptance of evolution (Barnes et al. 2021).

This study builds on previous research indicating that reducing perceived conflict among university students can significantly increase their acceptance of evolution (Barnes et al. 2017; Brem et al. 2003; Winslow et al. 2011). The CEBE suggested that acceptance of evolution is influenced by external factors, such as learning materials and strategies, and internal factors, such as a student's decision to consider alternative perspectives (Athanasiou et al. 2012). However, it is essential to note that students who do not accept human evolution feel uncomfortable with the course content, regardless of the species context (Grunspan et al. 2021).

Additionally, survey findings consistently reveal greater opposition to human evolution compared to other aspects of evolution (Brenan 2019). This opposition also comes from religious students where they are more comfortable with the idea of microevolution compared to human evolution (Betti et al. 2020). In fact, other research found that although many students accept microevolution, human evolution is often met with scepticism (Barnes et al. 2020a, b).

For students of religion, discomfort with human evolution may be greater because of perceived conflicts with their religious beliefs. Using human examples in evolution lessons can increase discomfort, decrease engagement, and ultimately inhibit acceptance of evolution (Grunspan et al. 2021; Nadelson and Southerland 2012). Therefore, it is essential for learning materials and teaching strategies should be designed to foster acceptance of evolution (Gregoire 2003; Southerland and Sinatra 2005). Furthermore, these empirical studies implied that reducing students' perceived conflicts can be done during evolution instruction (Barnes et al. 2017; Barnes et al. 2020a, b; Truong et al. 2018). According to the theory of conceptual change and the paradigm shift in science education, a constructivist approach can be an effective teaching framework for resolving the tension between evolution and religion (Reiss 2010). These strategies should promote learning that can reconcile the theory of evolution and religious beliefs (Asghar et al. 2010, 2014).

Religious beliefs should not hinder students from knowledge and supporting theory of evolution. Discussing creationism could potentially resolve socio-cognitive conflicts that arise among students (Foster 2012). For example, one way to reduce perceived conflict is that university students do not have to reject religious beliefs to accept evolution (Barnes et al. 2021). Religion is an integral part of CEBE that should be noticed (Athanasiou and Papadopoulou 2012). Trani (2004) showed that religious belief is one of the factors related to the acceptance of theory of evolution. However, creationism is a serious issue that may lead some people to reject the theory of evolution (Athanasiou et al. 2016). Previous research reported by Verhey (2005) on approaches to teaching evolution requires a deeper investigation. Creationism as a teaching habit in Islamic universities should be one of the considerations in evolution teaching. It is essential to ensure that the teaching of evolution is culturally sensitive and respectful towards existing values to avoid conflicting views (Aikenhead and Jegede 1999). Considering social and cultural consequences is an attempt to address affective factors as the factor that emerges more strongly when studying evolution (Deniz et al. 2008).

Furthermore, learning considering NOS not only enhances knowledge of evolution (BouJaoude et al. 2011; Cofré et al. 2017) but also has the potential to change students' views on science and religion conflicts (Stears 2012). More specifically, the prominent researchers in the field of theory of evolution acceptance prioritise developing NOS understanding in their students (Athanasiou et al. 2012; Nelson et al. 2019; Rutledge and Mitchell 2002; Rutledge and Warden 1999; Scharmann 2018). Even though numerous debates exist on the discussion of the NOS, the understanding or perception of NOS is conceptualised as the attitude or emotional perspective of science (Aikenhead et al. 1989). Thus, NOS should be considered an affective factor. According to initial opinions, understanding NOS is considered "affective" rather than cognitive because NOS is generated as a by-product of "doing science" and is referred to as a "scientific attitude" (Lederman et al. 2013). Therefore, this research used instruments that focused more on values and feelings, where the items relate to students' attitudes toward or appreciation of science and scientists related to evolution (Lederman et al. 2002).

Several previous studies also explained that NOS perception is needed for students to learn evolution effectively (Bell et al. 1998; Farber 2003). In addition, incorporating NOS into the teaching of evolution is more effective with a constructivist rather than a scientific-mechanistic approach, as it allows for a direct reflection of reality (Deniz et al. 2008). Several researchers recommended teaching NOS because it aligns with constructivist principles of science instruction (Lederman and Abd-El-Khalick 2002), and this approach is considered feasible to advance evolutionary knowledge (Alters and Nelson 2002).

Broadly speaking, this study focused on the changes in university students' CEBE following an evolution course, emphasising the balance of NOS and creationism. In particular, this study investigated whether changes in affective factors as CE occurred when conceptual changes occurred. Given the lack of research on Muslim university students' CEBE, there needs to be a significant focus in our knowledge on how teaching can reduce university students' perceived conflict between religion and evolution. Therefore, it is unknown to what extent conflict can be reduced and what the contribution of NOS and religiosity is in predicting university students' acceptance of evolution after evolution teaching. The research questions to guide this research are the following.

1. To what extent does some factor on CEBE improve from the pre-course to the post-course?
2. What is the relation between factors in CEBE in the pre-course and post-course?
3. To what extent do the contributions of knowledge increase and influence the acceptance of evolution in the post-course?
4. To what extent do perceptions of evolution NOS increase and influence the acceptance of evolution in the post-course?

5. To what extent do the contributions of perceived conflict decrease and influence the acceptance of evolution in the post-course?

Method

The research methodology used a concurrent mixed-methods approach (Creswell 2014). This research design emphasises that evolution learning has been highly complex and multifactorial in higher education (Greene 2008). This design combines all datasets to comprehensively view evolution pedagogy (Bazeley 2015; Burch and Heinrich 2016).

The quantitative data contributed to provide information on the impact of evolution learning on students' affective. The quantitative data provided information about students' acceptance of learning evolution and its correlation with their knowledge, religiosity level, and other affective factors. These affective factors included perceived conflict, the nature of science, thinking disposition, epistemological beliefs, and perceptions of the impact of the theory of evolution. At the same time, qualitative data was collected to examine students' knowledge of evolution, perceptions of NOS, and students' affective on the relationship between science and religion. Therefore, the data triangulation approach was designed to enhance the accuracy of interpreting the quantitative data.

Broadly speaking, quantitative data serves as the core of this research, while qualitative data is used as triangulation data. For ease of data collection, quantitative data was collected first, followed by qualitative data. The mixing process was performed during the data interpretation phase.

Group study design

This study employed a one-group pre-test post-test design (Marsden and Torgerson 2012) to pilot further evolution learning for Islamic Universities in Indonesia. 141 third-year biology study program students aged 20–22, which was dominated by women (81.5%), the Faculty of Science and Technology at the Universitas Islam Negeri Maulana Malik Ibrahim Malang formed a study group. We informed all of the Muslim students about the purpose of this study, which was to evaluate the effectiveness of the pilot program for Islamic education. Before starting the study, we obtained signed consent forms from all participants for ethical considerations. All procedures were approved by the institutional ethics committee (Mehlich et al. 2017).

We chose to study Muslim students in Indonesian Islamic Universities as a unique population. They were considered a religious community and a reinforcement of liberal thinking to break the orthodox hegemony (Hosnan 2019; Khoeroni 2017). The population at Indonesian Islamic Universities can provide an ideal model for studying acceptance of evolution as many Muslim communities were among the most sceptical (Downie and Barron 2000).

Learning intervention

The primary purpose of the evolution course was to promote students' mastery of evolution concepts as a theme while considering Islamic teachings. This consideration was taken about the university curriculum organised by the Ministry of Religious Affairs, which supports a vision of integrating science and Islam (Chanifah et al. 2021). The evolution course began with a general chapter on evolution, including an introduction to the nature of science (NOS). Towards the end of the course, students were taught about Islam and theory of evolution, specifically the creationist perspective. In sum, this course was designed to provide a balanced learning experience on theory of evolution by highlighting the relationship between the nature of science and creationism. This approach aimed to represent the balance between science and religion, serving as a form of reconciliation between them. The design followed the suggestion made by Barnes et al. (2017) that it is essential to teach students about the limitations of science and the religious figures who support the concept of evolution and to raise awareness about the range of perspectives on the relationship between religion and theory of evolution. The learning outcomes, content, and required time of the intervention part during 14 weeks are summarised in Table 1.

The learning approach utilised was constructivist through problem-based discussions (90 min for each meeting). Students were assigned worksheets or topics to discuss in their papers during each meeting. The discussion topics were selected by the lecturer. One group of students presented their work while the others asked questions (45 min). All students were given time to think about the answers to these questions individually. Then, they responded and complemented each other answers (30 min), while the lecturer became a facilitator during this activity. At the end of the discussion, the lecturer clarified any questions and asked students additional questions to enrich the discussion (15 min).

To ensure proper implementation of the learning process, especially concerning the NOS and creationist perspective, the two lecturers who taught evolution held weekly discussions with the researcher, particularly at the beginning and end of the semester. The discussions began at the start of the semester, and any changes in the lecturer's behaviour were observed. The main author observed each evolution class to ensure that evolution

Table 1 The outcomes, content, and duration of learning

No	Learning outcomes	Learning content	Duration
1	Ability to explain evolution as a valid theory	1. Definition and evolution scope 2. The nature of science, the process, and the science as a human endeavour 3. Theories of the origins of life; theories of the establishment of the earth 4. Evidence of evolution (fossil remains, comparative anatomy, other skeletal features, and others)	Four weeks
2	Ability to describe various mechanisms of evolution from the genetic perspective	1. Mutation; migration; and genetic drift 2. Natural selection; sexual selection; artificial selection; adaptation 3. Coevolution; example (case study)	Three weeks
3	Ability to distinguish between microevolution and macroevolution	1. Biogeography; speciation; domestication 2. Microevolution (definition, detection, and mechanisms); macroevolution (definition and patterns) 3. Fossils and geological time; molecular palaeobiology, molecular clocks	Three weeks
4	Ability to demonstrate opinions and positions on evolution by considering the relation between science and Islam	1. Phenomena of organismal evolution (homo evolution such as brain, food, bipedalism and tool evolution) 2. Darwin's opinions and the thoughts of pro and con Darwinists 3. Timeline of the controversy over evolution and religion; Muslim philosophers' thoughts on evolution; Nidahl Quessoum's thoughts	Four weeks

teaching was consistent with the intervention designed in the study. Improvements were suggested based on the results of the regular discussions. The lecturers in the class were committed to teaching evolution from an evolutionist and creationist perspective to reflect the integrated teaching of science and Islam.

Instrument

The data for the study was collected using a questionnaire consisting of eight main sections. These sections included the theory of evolution acceptance scale, knowledge and religiosity level, perceived conflict, nature of science, epistemological beliefs, thinking disposition, and perceived impact of theory of evolution. The Measure of Acceptance of the Theory of Evolution (MATE) has been frequently used in previous studies as the primary measure of acceptance due to its easy accessibility (Sbeglia and Nehm 2019), high reliability (Barnes et al. 2019), and simplicity, as it is a single-factor measure (Rutledge and Warden 1999). Additionally, the Inventory of Student Evolution Acceptance (I-SEA) was also employed to develop a more refined measure than MATE by providing the evolutionary context of human evolution and macroevolution (Nadelson and Southerland 2012). In addition, student religiosity was measured by exploring students' perceptions of the relationship between religion and evolution or creationism (Koenig and Büssing 2010; Manwaring et al. 2018; Silva Bautista et al. 2017) and students' understanding of theory of evolution based on the Koran.

Evolution Content Knowledge (ECK) was a questionnaire developed by Nehm and Schonfeld (2007). It consists of a 5-point Likert scale, which is highly suitable for research purposes. The scale allows for structural analysis, which can provide a more comprehensive interpretation of the findings regarding relationships with other variables. In fact, Athanasiou et al. (2016) have changed the initial version from Rutledge and Warden (1999) into a scale consisting of 17 items with a 5-point Likert scale. However, for reasons of avoiding the use of long tests and to maximise student responses (Gefaell et al. 2020), the ECK was more suitable to use in this research because it only has 8 statement items or half the number of scales in the version of Athanasiou et al. (2016). This research provided empirical evidence that can strengthen the idea that MATE and ECK can be another practical combination option, which, as far as we know, has only been carried out by researchers from Korea (Kim 2016; Kim and Nehm 2011).

Evolution and the Nature of Science (ENOS) was a questionnaire developed by Nehm and Schonfeld (2007). ENOS consists of only eight statements, which makes it easier to use and analyse correlations. From previous research, ENOS has also been proven to be a practical combination with ECK (Kim 2016; Kim and Nehm 2011). Apart from that, the instrument used to measure epistemological beliefs was a scale developed by Wood and Kardash (2002) and thinking disposition using the Actively Open-Minded Thinking (AOT) scale (Sá et al. 1999). As has been used by several previous studies (Athanasiou and Papadopoulou 2012; Deniz et al. 2008), these two instruments are

Table 2 General information and reliability items of the questionnaire

Variable	Instrument	Total number of items	References	Pre-test	Post-test
Acceptance	■ Measure of Acceptance of the Theory of Evolution (MATE) ■ Inventory of Student Evolution Acceptance (I-SEA)	28	(Nadelson and Southerland 2012; Rutledge and Warden 1999)	0.98	0.98
Knowledge	Evolution Content Knowledge (ECK)	8	(Nehm and Schonfeld 2007)	0.96	0.98
Religiosity	■ Duke University Religion Index ■ Intrinsic religiosity ■ Scriptural narrative	21	(Beniermann 2019; Koenig and Büssing 2010; Manwaring et al. 2018; Teixeira 2019)	0.99	0.99
Perceived conflict	Perceived Conflict between Evolution and Religion (PCoRE)	5	(Barnes et al. 2021)	0.97	0.86
Nature of science	Evolution and the Nature of Science (ENOS)	9	(Nehm and Schonfeld 2007)	0.99	0.99
Thinking disposition	Actively Open-minded Thinking Scale (AOT)	17	(Janssen et al. 2020)	0.97	0.98
Epistemological beliefs	Epistemological Beliefs Surveys (EBS)	38	(Wood and Kardash 2002)	0.99	0.99
Perceived impact of evolutionary theory	Perceived impact of evolutionary theory scale	10	(Brem et al. 2003)	0.98	0.98

considered a practical combination because they have the same ancestor, precisely the epistemic measure of Schommer (1990). According to DeBacker et al. (2008), the scale developed by Wood and Kardash (2002) showed higher internal consistency as compared to other epistemological belief instruments such as the Epistemological Questionnaire (EQ) and the Epistemic Beliefs Inventory (EBI). Finally, to measure students' conflicting perceptions and views regarding understanding the impact of evolution on individuals and society, we used a questionnaire instrument developed by Barnes et al. (2021) and Brem et al. (2003). These two instruments are still the only ones available and have good reliability.

Before being administered in the pre-test and post-test measurements, all instruments were validated by at least three experts to ensure content validity. The questionnaires were presented in the Indonesian language. Rasch analysis was used to calculate the item reliability of the pre-test and post-test questionnaires to ensure internal consistency. The maximum time given to students to complete all questionnaires was 120 min. The results showed that most estimates were above 0.9 (Table 2), indicating that the sample size was sufficient to confirm the construct validity of the instruments and reached at least 3 or 4 levels of separation (Cordier et al. 2018; Linacre 2006). We showed item reliability in this study but did not compare it with the raw score. Rasch measurements, such as item reliability, can be more accurate than raw scores in generalising findings, as presented by Yang et al. (2018).

After completing the lesson and questionnaire, the students were presented with a reflective essay consisting of three open-ended questions. The reflective essay aimed to investigate the students' knowledge of evolution by explaining how natural selection works (RQ3), the nature of science by students' perception of evolution as science theory (RQ4), and perceived conflicts by explaining the relationship between chimpanzees and humans (RQ5). The maximum time given to students to answer these questions was 30 min. Three questions are given to the student as follows.

1. Can you please explain how natural selection works?
2. What are your thoughts on evolution? Is it a theory yet to be proven or a fact?
3. Could you help me understand the relationship between chimpanzees and humans? Is it accurate to say that chimpanzees are our ancestors?

Data analysis

Out of the 141 students, five were excluded due to missing the pre-test and post-test or attending less than 80% of the 14 meetings. According to the abstract coding technique that was chosen and known only to each student, the questionnaires were identified and paired in the pre-test and post-test measurements.

Quantitative data analysis techniques were used to analyse the data, including descriptive and inferential statistics. The first step was to calculate the mean (M), standard deviation (SD), maximum (Max) and minimum (Min) scores of the responses on the pre-test and post-test. A paired t-test was then performed to determine the level of difference between the mean scores. This analysis helped to estimate the change in acceptance and knowledge of theory of evolution, religiosity level, and affective factors. To prepare for the regression analysis, we conducted an intercorrelation analysis between the variables using the Pearson-product-moment correlation statistical technique. This analysis was intended to determine how each measured construct related to each other. Finally, we conducted a regression test to calculate the contribution of each variable (explaining variable) to the variable of acceptance of theory of evolution. The regression test involved hierarchical (or sequential) regression analyses.

Regarding the analysis of qualitative data, we used content analysis techniques. Firstly, we coded the data from the students' written statements individually. In the next step, we created categories and themes. Finally, we calculated the frequencies supported by direct quotes from the students' answers. To ensure the results' reliability, we involved a coder and a co-coder who independently and separately coded the students' responses. The agreement between the two coders was calculated using intercoder kappa. If there were any differences between the two coders, they were resolved through discussion. The agreement between the two inter-coders reached more than 85%.

Results

Quantitative

The estimation of acceptance, knowledge, religiosity level, and affective factors before and after the intervention

After teaching, we found that almost every factor increased except perceived conflict, which decreased. However, we noted that only acceptance ($t=6.594$, $p=0.000$), NOS factor ($t=4.318$, $p=0.000$), and perceived impact ($t=3.901$, $p=0.000$) increased significantly after the science and religion dialogue teaching (Table 3).

The relationship between theory of evolution acceptance, theory of evolution knowledge, religiosity, and affective factors

We found a positive and relatively weak correlation between students' acceptance and knowledge in both pre-course ($r=0.241$, $p<0.01$) and post-course ($r=0.391$, $p<0.01$). This finding showed that university students with higher knowledge could better accept the theory of evolution. The same pattern also occurred in the aspects of NOS and perceived impact. The NOS was positively correlated relatively weakly with acceptance in the pre-course ($r=0.295$, $p<0.01$) and showed a relatively strong correlation in the post-course ($r=0.549$, $p<0.01$). Meanwhile, students' perceived impact had a positive and weak correlation with acceptance in the pre-course ($r=0.208$, $p<0.05$) and slightly strengthened in the post-course ($r=0.344$, $p<0.01$).

A different pattern has occurred for the religiosity and perceived conflict measurement. We found no correlation between religiosity and acceptance in the pre-course ($r=0.086$, $p>0.05$) but a positive correlation in the post-course ($r=0.284$, $p<0.01$). On the contrary, students' perceived conflict had a negative correlation with acceptance in the pre-course ($r=-0.279$, $p<0.01$)

Table 3 Students' CEBE after teaching

	Mean Pre-course	Mean Post-course	Mean difference	*t*	*df*	Sig (2-tailed)
Students's CEBE (N = 141)						
Acceptance	93.61	99.98	6.37	6.594	140	0.000
Knowledge	26.87	27.31	0.44	1.809	140	0.073
Religiosity	87.68	88.09	0.41	0.907	140	0.366
Perceived conflict	16.86	16.61	−0.25	−0.979	140	0.330
NOS	27.91	28.99	1.08	4.318	140	0.000
Thinking disposition	53.73	54.37	0.64	1.242	140	0.216
Epistemological belief	114.11	115.04	0.93	1.630	140	0.105
Perceived impact	31.27	32.43	1.16	3.901	140	0.000

and did not correlate with the post-course ($r=-0.158$, $p>0.05$). These results demonstrated that student religiosity positively influenced post-course acceptance and decreased perceived conflict. Our participants had perceived conflict on the item "I have difficulty believing that humans have changed over time due to evolution", with the most reasons for 57 students due to their personal religious beliefs. Only two students reasoned that the perceived conflict was due to the religious community.

The participants in our study were Muslim students considered religious, almost all of whom prayed five times a day and attended religious activities at least once a week. Other than that, only four students declared themselves as people who interpret the Koran textually. Most university students reported themselves as capable of pursuing creativity to enhance science while holding on to religious values.

The dispositional thinking was uncorrelated with the acceptance of evolution in both pre-course ($r=0.033$, $p>0.05$) and post-course ($r=0.076$, $p>0.05$). Similarly, the epistemological beliefs (pre-course $r=0.044$ $p>0.05$, post-course $r=0.081$, $p<0.05$). These results indicated that the students did not experience significant cognitive flexibility and openness to belief development, although they showed increased acceptance of evolution.

Most importantly, students' knowledge only showed positive correlations with religiosity ($r=0.341$, $p<0.01$), NOS ($r=0.256$, $p<0.01$), and perceived impact in the

Table 4 Intercorrelation among acceptance, knowledge, religiosity, and affective factors

	Acceptance	Knowledge	Religiosity	Perceived conflict	NOS	Thinking disposition	Epistemological belief	Perceived impact
Pre-course								
Acceptance	1							
Knowledge	0.241**	1						
Religiosity	0.086	0.102	1					
Perceived conflict	−0.279**	−0.041	−0.074	1				
NOS	0.295**	−0.009	0.002	−0.146	1			
Thinking disposition	0.033	−0.080	0.007	0.036	0.395**	1		
Epistemological belief	0.044	−0.063	0.072	−0.098	0.368**	0.613**	1	
Perceived impact	0.208*	0.055	0.206*	−0.118	−0.023	−0.052	−0.136	1
Post-course								
Acceptance	1							
Knowledge	0.391**	1						
Religiosity	0.284**	0.341**	1					
Perceived conflict	−0.158	−0.204**	−0.46	1				
NOS	0.549**	0.256**	0.277**	−0.229**	1			
Thinking disposition	0.076	−0.24	0.090	−0.092	0.174*	1		
Epistemological belief	0.081	0.055	0.121	−0.033	0.101	0.466**	1	
Perceived impact	0.344**	0.192*	0.229**	−0.173*	0.349**	0.031	0.019	1

**p < 0.01; *p < 0.05

Table 5 Summary of hierarchical regression analyses (pre-course)

Model	R	R square	Adjusted R square	Std. error of the estimate	Change statistics	
					R square change	F
1	0.241	0.058	0.051	8.87	0.058	8.581**
2	0.249	0.062	0.048	8.88	0.004	4.562*
3	0.364	0.133	0.114	8.57	0.071	6.980**
4	0.448	0.201	0.177	8.26	0.068	8.527**
5	0.450	0.203	0.174	8.27	0.002	6.872**
6	0.453	0.206	0.170	8.29	0.003	5.777**
7	0.481	0.232	0.191	8.19	0.026	5.727**

**p < 0.01; *p < 0.05

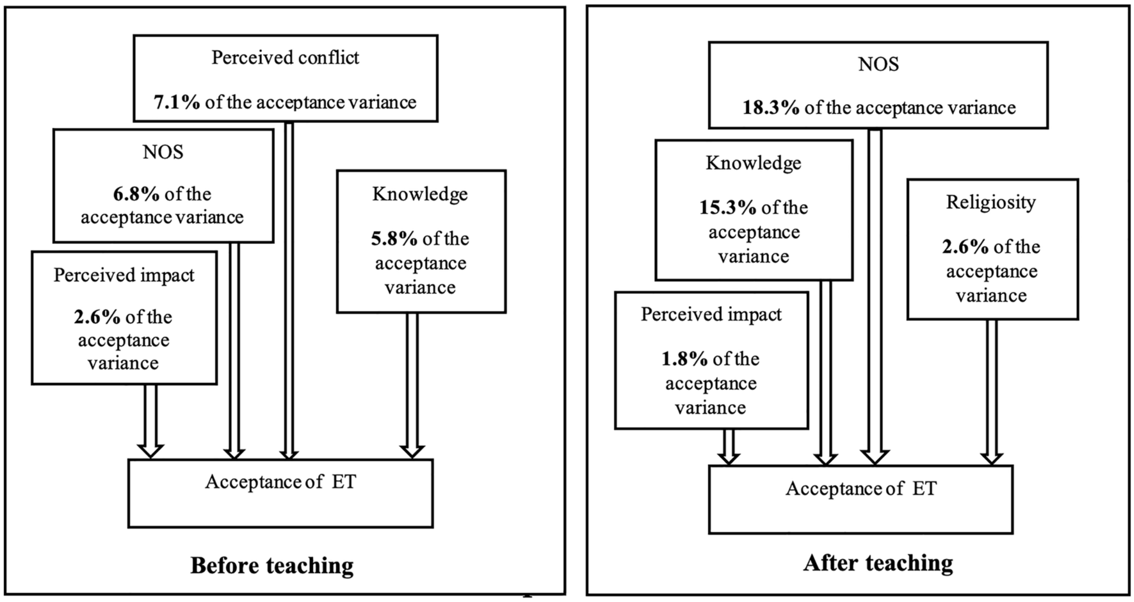

Fig. 1 The model of change in Muslim students' conceptual ecology to accept the evolutionary theory (ET)

Table 6 Summary of hierarchical regression analyses (post-course)

Model	R	R square	Adjusted R square	Std. error of the estimate	Change statistics	
					R square change	F
1	0.391	0.153	0.147	8.31	0.153	25.057**
2	0.423	0.179	0.167	8.21	0.026	14.995**
3	0.426	0.181	0.164	8.23	0.002	10.124**
4	0.603	0.364	0.345	7.28	0.183	19.451**
5	0.603	0.364	0.340	7.31	0.000	15.447**
6	0.693	0.364	0.336	7.33	0.000	12.792**
7	0.618	0.382	0.350	7.26	0.018	11.748**

**p < 0.01; *p < 0.05

post-course ($r = 0.192$, $p < 0.05$). On the other hand, students' knowledge showed a negative and relatively strong correlation with perceived conflict in the post-course ($r = -0.204$, $p < 0.01$). The religiosity, NOS, and perceived impact factors seemed to affect acceptance and knowledge after the teaching. In the meantime, perceived conflict had an inverse effect, which indicated that the higher the students' knowledge, the lower the students' perceived conflict after teaching. Table 4 summarises the correlation of acceptance with knowledge, religiosity, and affective factors in pre-course and post-course.

Estimation of the contribution of independent variables (explaining variables) to acceptance

In the pre-course measurement (Table 5 and Fig. 1), the factor that has the most significant contribution was perceived conflict at 7.1%, followed by the NOS factor in the second position at 6.8%. The third factor that contributed was knowledge, at 5.8%. Another factor that contributed significantly above 1% was perceived impact (2.6%). Knowledge, religiosity, and affective factors contributed 19.1% to the acceptance of the theory of evolution.

In the post-course (Table 6 and Fig. 1), the NOS factor made the most significant contribution, accounting for 18.3% of the variance in acceptance. At the same time, the knowledge factor was in the second position with a contribution of 15.3%. Religiosity was also the most significant factor contributing to evolution acceptance (2.6%) besides perceived impact (1.8%). Overall, knowledge, religiosity, and affective factors contributed 38.2% to the acceptance of the theory of evolution.

Qualitative

Hierarchical regression analyses pre-course (Table 5) and post-course (Table 6) show three factors related to CEBE whose changes stand out. As presented briefly in Fig. 1, knowledge and NOS were the factors that increased the most, while perceived impact decreased. This qualitative data was provided to complement and strengthen the essential findings of these three factors. First, how students' knowledge did not increase but made a significant contribution related to the many students who still used naive explanations about natural selection. Second, students' improving understanding of NOS and making significant contributions were reflected in the views of most students who accept evolution because there was strong evidence, even though they admit that there was controversy. Third, the perceived impact, which decreased and made a significant contribution, can be seen from the pattern of students' answers, which mainly use mechanistic explanations. More details will be presented in the next section, supported by students' perceptions.

Knowledge

According to our study, more than half of the participants (55.3%) showed naive reasoning when answering questions about natural selection. This group of students demonstrated a simplistic understanding of natural selection, often portraying it as a deliberate process to enhance species. They frequently used teleological language, indicating a misconception that evolution leads to progress (in bold). Some selected examples of students' explanations that align with naive reasoning are as follows:

> *"Natural selection occurs when organisms with* **preferential characteristics** *survive and thrive to* **produce excellent generations***" #12 (Medium score)*
> *"Natural selection is a process that occurs naturally. Living things* **that can adapt to their environment** *will survive, and the others will die" #128 (High score)*
> *"Natural selection is characterised by selecting organisms* **that can survive** *and reproduce in changing conditions. Organisms* **that can survive and adapt well** *will be more challenging to choose and vice versa' #151 (Medium score)*

Of the total number of students, 35 (24.8%) demonstrated an acceptable level of adaptive reasoning. This group of students showed a better understanding of natural selection than those who relied solely on naive reasoning. They were able to identify important concepts such as reproductive success and the influence of environmental factors. Although their understanding of evolutionary processes still needs improvement, their knowledge has progressed. The most commonly identified critical concepts in their responses were fitness and genetic variation. We provide three examples of the students' explanations where key concepts were used (underlined):

> *"Natural selection refers mostly to the success of breeding by increasing the attractiveness of an organism (competition for females). The results are offspring, so natural selection can also be said to be sexual selection" #54 (Medium score)*
> *"Natural selection is the natural process of selecting species that can survive. Natural selection is fitness, where the strongest living things will lose out to those healthy enough to find a mate and have offspring. During this process, it may also be caused by natural disasters" #77 (High score)*
> *"Natural selection works by selecting the variation in the population, who will survive and who will be eliminated. Natural selection will be successful if gene variations and environmental factors can encourage genetic drift. Apart from that, individuals can inherit their traits to the next generation" #118 (High score)*

Our recent study discovered that 28 students (19.6%) exhibited partial-mixed reasoning. This group demonstrated a combination of understanding and confusion regarding natural selection. Although they included important concepts such as genetic variation and environmental factors, they also perpetuated misconceptions and used ambiguous language. Their responses indicated a blend of comprehension and misunderstanding, where students tried to demonstrate some knowledge of natural selection by including the key concepts (underlined) along with other unclear terms and misconceptions (in bold):

> *"Natural selection works by producing* **individuals resistant** *to an environment with certain stresses, and individuals unable to resist will die. Natural selection requires genetic variation, limiting factors (such as food availability), and mating that produces an excellent individual suited to the environment." #74 (High score)*
> *"Due to genetic variation, natural selection will select individuals who can* **survive in a certain environment** *so that only* **excellent individuals** *survive. These individuals will then reproduce and have excellent offspring." #108 (High score)*
> *"Natural selection creates* **less or less appropriate conditions** *for specific organisms. Eventually, selection will cause* **the organism to adapt***. The organisms that can adapt will have fitness and are the survivors of the selection." #154 (High score)*

It is important to note that while a high score indicated a better understanding of natural selection, it did not necessarily guarantee flawless comprehension. High scores implied that students have a solid grasp of key concepts and can articulate them well, but there may still be minor inaccuracies or ambiguities in their statements. On the other hand, medium scores suggested a basic understanding of natural selection, but there is still potential for improvement. These students might have grasped fundamental concepts but need guidance in articulating them clearly or fully understanding the underlying mechanisms.

Nature of science

In this study, we considered categorising student responses into accepting evolution as a scientific and just a theory. In more detail, our participants were divided into three groups: the group that said evolution had strong evidence, the group that explained evolution as a scientific theory but had weak support for the theory, and the group that doubted that evolution was only a theory.

In the acceptable category, of the 141 students who participated, 103 (73%) provided an acceptable explanation of evolution. Despite being controversial, they described evolution as a scientific theory with solid evidence supporting it. These students acknowledged that evolution was responsible for the diversity of life forms on Earth, and its basis lies in empirical evidence. Some students also highlighted the dynamic nature of scientific understanding of the theory of evolution. Furthermore, it was noted that evolutionary theory has several confirmed facts through observations and experiments, but they were only sometimes well-confirmed. The following provides three examples of student descriptions where key concepts are used (underlined):

> *"Evolution as a theory can describe why population changes occur. <u>The changes and developments in the theory of evolution happen</u> because of the nature of science itself. These changes have strengthened the theory of evolution with <u>more scientific and well-accepted explanations</u>." #82 (Medium score)*
>
> *"Evolution is not merely a theory and <u>has evidence</u> that can be scrutinised. Nevertheless, the theory of evolution will continue to evolve along with new findings. The theory of evolution still <u>has loopholes</u> to be refuted, but the existence of clues and evidence of evolution, such as fossil diversity, is enough to prove that <u>evolution happened</u>" #114 (Medium score)*
>
> *"Evolution is evidence of human endeavour to understand why and how variation/diversity and the origin of living things. Thus, <u>the existence of debate loopholes within it is inevitable</u> and characterises evolution as a science. However, <u>evolution can be proven</u> in many different ways and conclude." #157 (High score)*

In response to evolution, 26 students (18.5%) fell under the category of presumption in support of it. These students acknowledged the positive evidence for evolution while also recognising the need for ongoing refinement and expansion of the theory, emphasising the iterative nature of scientific inquiry. In other words, they support evolution but call for further robust evidence and testing to improve the theory. Students believed that evolution still requires more robust evidence, as expressed by some students below (in bold):

> *"Evolution is an evidence-based theory that can explain the process of the origin of life from the past to the present through experiments and observations. However,* **there are still some gaps** *in the theory of evolution* **that can still be added** *with new information, and some statements in the theory of evolution need to be proven." #108 (Medium score)*
>
> *"Evolution is referred to as a theory because it can explain how the phenomenon of the diversity of living things can occur. Certainly, this explanation has a* **basis that can be***. However, as humans,* **we also find it difficult to confirm** *and prove because of our limited ability to understand changes in certain videos, but the existing evidence is* **sufficient to prove that evolution occurs***." #142 (Medium score)*
>
> *"Evolution is the theory that explains how populations change over long periods. Several irrefutable evidences exist, such as physiological, anatomical, and molecular comparisons. On the other hand, we can also say that the evolutionary theory still* **needs further study** *because the objects studied may continue to change and provide different evidence." #156 (High score)*

Out of the total number of students, 12 (8.5%) rejected the theory of evolution by stating that it is "just a theory." They expressed their personal preference and scepticism towards the validity of the theory of evolution. They also raised doubts about the reliability of scientific evidence and often cited dissenting opinions within the scientific community (underlined and in bold):

> *"Evolution is merely a theory* **<u>that has yet to be proven,</u>** *and* **<u>no conclusions</u>** *can be drawn" #11 (Medium score)*
>
> *"The theory of evolution is based on scientists' ideas, which are of* **<u>doubtful validity</u>***. The evidence*

provided is **insufficient,** *and many other scientists* **reject it***" #36 (Medium score)*

"The theories that support evolution are many and varied, but many of them **have not yet been proven***. In addition, there are* **debates** *between scientists and religious figures that make the* **validity of this theory even more questionable***. The reality of the theory put forward by scientists* **is just a theory***" #57 (Medium score)*

"The theory of evolution put forward by various experts **has not yet been proven correct,** *and this theory* **still needs to be proven** *from repeated observations and experiments" #112 (Medium score)*

Although high scores in science often indicate a strong understanding of scientific principles, when it comes to accepting scientific theories, medium scores can reflect the complexity of students' attitudes and knowledge levels. However, when rejecting scientific theories such as evolution, the absence of high scores suggested a potential disconnect between a robust understanding of the nature of science and the rejection of scientific principles. Therefore, while high scores generally reflect a good understanding of the nature of science, the absence of rejection may not necessarily indicate a deep comprehension of scientific principles.

Perceived conflict

The majority of students provided mechanistic explanations, demonstrating a scientific understanding of evolutionary concepts. These responses detailed the taxonomic relationship between humans and chimpanzees, highlighting evolutionary divergence and the shared ancestry between the two species. The following are some examples of student's responses:

"Humans belong to the Hominidae group along with chimpanzees, gorillas, orangutans and bonobos. Hominidae is divided into the subfamilies Pongo and Homoninae. Homoninae is divided into Gorillini (gorillas) and Hominini (chimpanzees and humans). Therefore, the last common ancestor of chimpanzee-humans is the last common ancestor shared by the genus Homo (humans) and Pan (chimpanzees), which are still part of Hominini." #39 (High score).

"Chimpanzees are closely related to humans. We have common ancestors who lived about 5–7 million years ago. Chimpanzees are the closest primate genetically to humans, with about 98% similarity. We have a shared ancestor that is the starting point for the development of the human and chimpanzee lineages" #69 (Medium score).

"The relationship between humans and chimpanzees is quite close. Both humans and chimpanzees have a shared primate ancestor from about 7 million years ago. Humans share a common ancestor with chimpanzees, bonobos, gorillas, and orangutans. Over time, these ancestors underwent evolutionary divergence, leading to the genetic and morphological changes known as the modern human species." #144 (High score).

Conversely, when students were asked if chimpanzees were human ancestors, they responded with a theological perspective, citing religious teachings to explain human origins as separate from other primates. Although some responses lacked integration with evolutionary science, others skillfully combined religious beliefs with scientific understanding, revealing a nuanced perspective on the conflict between religious and scientific explanations of human origins. These answers are directly from the student's descriptions:

"In Islam, the creation of humans is not because of the results of other primates, but the result of Allah's creation that makes humans perfect creatures. It has been clearly explained in Q.S. Al-Mukminun (12-14) that humans come from semen and are then made into a blood clot and a flesh clot, then bones, and encased in flesh." #48 (Medium score)

"In the creation, humans are different from chimpanzees. The two have a genetic relation, but they can not be said to be in the same lineage. In QS. At-Tin (4) explained that "Allah SWT has created man in the best physical and psychological form". This means that humans are creatures created with physical, mental and intellectual perfection. In contrast to animals that are not endowed with reason." #154 (High score)

"From the religion's point of view, chimpanzees are not the ancestors of humans. This is very much against the teachings of my religion, wherein the Koran clearly stated that the first human being was the prophet Adam. Allah created humans from the first descendants of Adam and continues to this day. In Q.S. As-Sajdah (7-9), it is explained that the creation of man came from the ground in the best possible form. Then, make his descendants from the semen" #158 (High score)

The majority of the students displayed a high level of understanding of evolutionary concepts and taxonomy by providing mechanistic explanations. Their high-scoring responses accurately detailed the taxonomic relationship between humans and chimpanzees, emphasizing their shared ancestry and evolutionary divergence. However, when asked if chimpanzees were human ancestors, some students responded theologically, citing religious teachings from the Koran. Although a few students provided high-scoring responses that integrated religious perspectives with evolutionary science, others offered medium-scoring responses that focused solely on religious narratives without addressing evolutionary concepts.

Discussion and conclusion

The present study is the first attempt to explore the factors associated with accepting Muslim biology students' theory of evolution using the CEBE theoretical lens in Indonesia. Each country and university has different curricula and sociocultural environments, so Islamic Universities in Indonesia have local characteristics and conditions. CEBE suggested that many factors may control evolution learning (Athanasiou et al. 2012). Thus, we considered this step more promising than just focusing on the single factor of accepting theory of evolution (Athanasiou and Papadopoulou 2012; Sinatra et al. 2014). These are compelling arguments in support of CEBE research in the context of Islam and Indonesia and comparing the findings with research results in other countries.

The major finding showed a significant change followed by an increased acceptance of theory of evolution in NOS. Hence, evolution acceptance may be changing as a result of evolution instruction. Similar reports came from previous studies (Athanasiou et al. 2012, 2016; Athanasiou and Papadopoulou 2012). Other findings were that the strengthened factors contributing to evolutionary theory acceptance after the course were NOS, knowledge, and religiosity. Meanwhile, perceived conflict decreased considerably. The change in CEBE can be attributed to evolution teaching interventions that emphasised the balance between science and creationism. In general, science education that considers religious perspectives positively impacts knowledge and affective aspects (Purwati et al. 2018; Suciati et al. 2022a, b). Recent research confirmed that incorporating discussions of religion and science into teaching about evolution impacts students' acceptance of evolution (Bernhard et al. 2023). Teaching designs that combine NOS aspects and explore the relationship between religion and science is very promising for reducing perceptions of conflict (Dunk & Wiles 2018; Nelson et al. 2019; Yasri & Mancy 2016). Barnes & Brownell (2017) developed a framework, Religious Cultural Competency in Evolutionary Education (ReCCEE), and they propose teaching practices that encourage students to discuss and explore their views about evolution and religion.

Our study also examined the impact of teaching evolution on knowledge. Contrary to our initial expectations, we found that teaching evolution did not significantly increase students' factual knowledge of evolution. This finding was significant given the common assumption that educational interventions, such as those conducted in our study, usually lead to increased conceptual knowledge.

Interestingly, although our study did not find a significant increase in knowledge immediately after the intervention, our analysis revealed that understanding played an important role in fostering acceptance of evolution among Muslim students. Knowledge showed a relatively high contribution and strengthened in the post-course. These unexpected results indicated that although this intervention may not have immediately impacted knowledge acquisition, it may have laid the foundation for students' future understanding of evolution, influencing their acceptance of evolution.

Many previous research findings support our focus on acceptance rather than knowledge as an outcome of instruction. Other studies suggested that an increased knowledge of evolution leads to higher acceptance (Athanasiou et al. 2012, 2016; Athanasiou and Papadopoulou 2012). Furthermore, the relationship between knowledge and acceptance in the present investigation needed to be stronger, as Rutledge and Warden (2000) and Athanasiou et al. (2012) reported. Several studies have demonstrated a link (Deniz et al. 2008; Lawson and Worsnop 1992; Trani 2004), and studies have refuted these findings (Bishop and Anderson 1990; Demastes et al. 1995a, b; Sinatra et al. 2003).

According to the university students' qualitative answers, most showed naive notions in the evolutionary explanation. These results contrasted with a more recent study by Caño and Ormazabal (2023). Only a few students succeeded in giving answers by bringing up key concepts such as variation, mutation, and fitness for natural selection (Mayr 2002). Some showed a mixed interpretation of naive and scientific notions. The results of this mixed analysis simultaneously suggested that students still believe in adaptation as a process involving intentionality. Obviously, this may be not only a linguistic problem, as reported by previous studies (Caño and Ormazabal 2023; Geraedts and Boersma 2006), but also an issue of conceptual knowledge that has not changed much.

NOS has been the most significantly improved factor on CEBE, significantly correlated with acceptance, and has strengthened the contribution to theory of evolution acceptance. For instance, NOS is a significant and foremost factor that has made a statistically significant positive contribution to predicting participants' acceptance of evolutionary theory (Akyol et al. 2010). Over the past decade, previous research showed that NOS has been proven to correlate significantly with the acceptance of theory of evolution. Over the past decade, multiple studies have consistently shown a significant relationship between an individual's understanding of NOS and their acceptance of evolutionary theory (Athanasiou et al. 2016; Cofré et al. 2017; Gefaell et al. 2020; Kim and Nehm 2011). However, it is important to note that while scientific research supports these correlations, it does not provide definitive proof. Moreover, the content analysis of reflective essays conducted after the course showed that the number of students who gave answers accepting evolution was higher than those who rejected it. Most students gave statements from the viewpoint of the scientific nature of the theory of evolution. They respond that theory of evolution has provided answers to the diversity of living things today and has enough evidence, although it has been controversial. The theory of evolution stated that it lacked evidence and was just a theory among the opinions that rejected it.

On the other hand, in the case of our evolution teaching, the association between thinking dispositions, epistemological beliefs, and the acceptance of theory of evolution is contradictory to the previous studies. The present research contradicted previous findings (Athanasiou et al. 2012, 2016; Athanasiou and Papadopoulou 2012; Deniz et al. 2008), which showed that people with higher levels of open-mindedness were more likely to accept theory of evolution, although in people with higher religiosity (Athanasiou et al. 2012, 2016; Athanasiou and Papadopoulou 2012). In other words, it is also contrary to Deniz et al. (2008) and Cho et al. (2011), who stated that students' epistemological beliefs influenced students' acceptance more, which was even higher than beliefs about the nature of science (Cho et al. 2011).

Furthermore, a high level of evolution acceptance did not represent more open-minded students, as described by Sinatra et al. (2003) and Deniz et al. (2008). Perhaps this could also explain the unchanged acceptance of evolution and low knowledge acquisition after teaching. Indeed, there seemed to be cases where students may have accepted theory of evolution without openness, while in other cases, it may have been thinking and epistemological dispositions that served as facilitators of acceptance. We contend that both opposing views may be correct when argued through the lens of CEBE. At the same time, whether these findings are associated with the NOS being taught or whether there may be factors beyond teaching, such as social and religious reasons, should be clarified.

Generally, we would like to emphasise that the present study concerned Muslim students who were religious as measured by the Duke University Religion Index (Koenig and Büssing 2010). The religiosity type in the present study appeared different and did not take a fundamentalist view. In contrast, the students with high levels of religiosity responded that they interpreted the Koran in a contextual way that could be aligned with what science explained after the intervention teaching.

We discovered that being a religious Muslim is not essential for rejecting evolution theories that are based on scientific aspects. However, these findings contrast with Athanasiou and Papadopoulou (2012) findings that showed a negative correlation between theory of evolution acceptance and religion. On the contrary, these findings indicated that an exciting outcome was that the students could accept the scientific aspects and evidence supporting evolution. On the other hand, they claimed to be religious, as shown in the post-course. As a result, Muslim students in Indonesia have unique characteristics: they showed high religiosity combined with good enough acceptance of evolution. These results demonstrated a decrease in the contribution of perceived conflict and impact. This is different from Brem et al. (2003), who stated that university students believe in several negative consequences for society (social) and themselves (personal) in the theory of evolution. On the contrary, the students in our case accepted the theory of evolution and believed that evolution neither leads to a decrease in spirituality, self-direction, and self-determination nor an increase in religiosity and racism. Indeed, research has documented that students' religiosity was unlikely to change with only evolutionary instruction (Kimball et al. 2009). The finding may be encouraging for evolution educators as religiosity is the most robust and predictive factor for students' post-course evolution acceptance.

Considering the answer pattern analysis related to the relationship between chimpanzees and humans, it appeared that students preferred not to imply integration. They acknowledge the plurality of religion and science by choosing not to accept scriptural narratives as scientific evidence and vice versa. Many forms of "religion" and "science" can be challenging to integrate with other forms. The results of this study are quite interesting as they differ from prior research. Asghar et al. (2014) explained that Muslim students accept evolution except human evolution because it contradicts their Islamic beliefs (Barnes et al. 2021). Students disagreed with items measuring acceptance of macroevolution and human evolution. Dajani (2015) stated that most Islamic students cited evidence from the Koran that interpreted humans as being created spontaneously. In other words, the topic of human evolution is still taboo because they are not ready to let go of the concept that humans were created differently.

These results also contradict the previous study's findings, which stated that students can interpret the scriptures literally (Lawson and Worsnop 1992) and use them as a fundamentalist belief to reject evolution (Miller et al. 2006). Interestingly, university students seem more likely to be religiously committed (Alters and Alters 2001) and to use theological reasoning instead of scientific reasoning (Miller et al. 2006) when scientific explanations conflict with literal interpretations of the scriptures. In summary, while the basis of the relationship between humans and chimpanzees did not provide a promising model for integrating science and religion equally well, it did not mean that some of the many non-creationist models and theological explanations involving science could not work and explain each other. In these discussions, students have formed more complex models that fit various understandings of science and religion without necessarily conflating them.

Notably, this pattern reflected that Muslim Biology students in Indonesia were a moderate group. These students have a culture that makes it almost impossible to put aside their education and old mindsets when confronted with scientific ideas. They accepted the explanation of creation described in the Koran and then examined the truth claims of evolution against the Koran. Instead, they might use SOMA (Softly Overlapping Magisteria). This approach minimally and gently elevates some religious ideas, i.e. without advocating for any particular perspective but simply recognising that several evolutionary topics may raise some religious issues and that there may be discussions and multiple perspectives on evolution and religion. This approach will tend to strike a balance between an understanding of the text and the use of logical reasoning. Accordingly, they tend to be selective, neither rejecting the theory of evolution entirely nor accepting it rashly.

The present findings of this research highlighted that teaching evolution can be designed to support the acceptance of evolution while building positively on students' religious beliefs. Concurrently, we argued that a teaching approach emphasising creationism would make more sense for Muslim student groups, where knowledge and beliefs rely heavily on scriptural descriptions and narratives. The present research has solved the future challenge by establishing a well-balanced teaching approach between the nature of science and creationism. Indeed, as our data suggest, this is a new element in evolution courses.

Based on this case, we also suggested approaching the idea of NOS and the meaning of theory in science as a balance. When the students start to conflict between religion and science, educators must develop a more integrative way of thinking about science. This approach is deemed more appropriate for achieving acceptance of evolutionary theory (Woods and Scharmann 2001). A teaching approach that emphasises the interpretation of scripture is equally essential as introducing students to NOS and the meaning of theory in science. In other words, both should be given in a balanced manner. This can change students' view of NOS, leading to scientific acceptance (Perry 1999). Students appeared to have some possibility of knowledge that the theory of evolution provided the best explanation for the appearance of living species and their diversity. In other words, a science and religion dialogue in the teaching of evolution may be needed to reduce the possibility of religious misinterpretation and, thus, anti-evolutionary theory as science or vice versa.

On the other hand, it is also crucial for educators to remember that they may encounter those who reject the theory of evolution even though students may be able to accept the scientific aspects of the theory of evolution. In this situation, educators need to pay attention to teaching NOS principles, as Clough and Olson (2008) suggested. It is crucial to explain that teaching often leads students to view NOS as something that can only be learned rather than as a tool for understanding how evolution operates as a science. As reported by Cho et al. (2011), although the belief in NOS was relatively high, it could not predict conceptual change. That, in turn, will affect students' acceptance, as in the case of our study.

Despite the limitation of this research that the design was one-group pre-and post-test, the findings of the data analysis revealed that the utilisation of the CEBE lens could provide a comprehensive picture: factors that have increased contributions (NOS, knowledge, and religiosity) and decreased significant contributions (perceived conflict and impact), and also remained without significant contributions (dispositional thinking and epistemological beliefs) towards the acceptance of evolutionary theory after the intervention. Further research needs to broaden the numbers in the study group, iterate the study by adding a control group, and provide a dispositional thinking approach to confirm and clarify these findings.

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Author contributions

M.S. contributed to conceptualisation, methodology, formal analysis, investigation, original draft writing, and research validation. H.S. contributed to conceptualisation, methodology, formal analysis, writing of the original draft and supervision of the research. Y. H. contributed to the formal analysis, investigation, validation, data curation and research resources. All authors discussed the results and contributed to the writing, review, and editing.

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Availability of data and materials

Available from authors upon request.

Declarations

Ethics approval and consent to participate
Ethics approval was granted by the Universitas Negeri Malang (project number 5.4.493). All participants signed terms of informed consent to publish, agreeing to participate in the research, and the identities of the participants were kept anonymous.

Competing interests
The authors declare they have no competing interests.

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